NSM

REPORT OF BOARD OF INQUIRY

INTO 275 kV. SYSTEM FAULT

ON SATURDAY, NOVEMBER 8TH, 1969

April 1970

CONFIDENTIAL

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BOARD OF INQUIRY INTO 275 kV. SYSTEM FAULT ON SATURDAY, NOVEMBER 8TH, 1969

PREFACE

On Saturday morning November 8th, 1969 at 03.06 hours lightning in the vicinity of Kilmarnock caused a flashover on both circuits of the Strathaven - Kilmarnock 275 kV. transformer feeders, teed to Ayr. As a result the supply to 54,000 consumers in Ayr and Kilmarnock was cut off, in most cases for a period of about $2\frac{3}{4}$ hours.

The fault on the No. 2 circuit was cleared correctly and on the No. 1 feeder the 33 kV. circuit breakers controlling the 120 MVA. transformers at Ayr and Kilmarnock, all operated correctly. Unfortunately the 275 kV. circuit breaker at Strathaven failed to trip due to a defective trip relay and thus left the No. 1 overhead line still energised with arcing on the overhead line and on the 120 MVA. transformer bushing. The bushing was set on fire and the arcing on the overhead line caused damage to insulators and conductors with the result that a number of conductors fell to the ground across the Hurlford road. A car ran into the conductors, skidded and overturned but the occupants only sustained superficial injuries.

The fire brigade and local section staff managed to limit the effects of the bushing fire.

The Grid Control staff were hampered in their attempts to isolate the fault by their inability to use the supervisory equipment to trip the Kilmarnock No. 1 feeder at Strathaven. They eventually were able to use other supervisory equipment to clear the circuits feeding into the faulted Strathaven busbar and the C.E.G.B. also opened the Strathaven feeder at Harker. The effect of the sustained fault was to cause most of the generators in Scotland to trip and also four generators at Blyth. Throughout the period of the fault low voltage conditions were experienced throughout Scotland and in parts of North East England. Immediately after the fault abnormally high voltage conditions were experienced with the result that consumers' equipment was damaged as well as some auxiliary equipment in the Board's generating stations. Approximately 302 MW. of load was shed in Scotland and 176 MW. in England in order to avoid overloading transmission lines and assist in restoring supplies. The fault was finally cleared at 03.34.

In view of the extent of the disturbance and the nature of the fault a Board of Inquiry was set up. The following document comprises a statement of the constitution of the Board of Inquiry, the Terms of Reference and the report of the Board. It also contains as appendices the evidence submitted to the Board.

SOUTH OF SCOTLAND ELECTRICITY BOARD

Board of Inquiry into 275 kV. System Fault
on Saturday, November 8th, 1969

Constitution of Board

The Board of Inquiry was set up in accordance with S.S.E.B. procedure authorised in Paper B.151/65 with the following membership:-

Chairman	Mr. F.L. Tombs	- Director of Engineering
	Mr. J. Addison	- Chief Engineer Transmission/Distribution
	Mr. J.C. Alderman	- Safety Engineer
	Mr. E.N. Davies	- System Operation Engineer
	Mr. R. McGlashen	- Manager, Central & South West Scotland Area
	Mr. W.L. Kidd	- Technical Consultant
	Mr. A.S. Ramsay	- Assistant Secretary, Legal
	Mr. G.R. Todd	- Chief Engineer Generation Operation

The C.E.G.B. and the North of Scotland Hydro-Electric Board were represented by:-

Mr. W. Kerss	- System Co-ordination Engineer, C.E.G.B.
Mr. W.A. Storey	- System Operation Engineer, N.E. Region, C.E.G.B.
Mr. J.K. Moffat	- Chief System Operation Engineer, H.E.B.

Terms of Reference

The Board of Inquiry were given the following Terms of Reference:-

1. To investigate the reason for the fault on the 275 kV. Strathaven/Kilmarnock lines on Saturday, 8th November.

2. To investigate the reasons for the delay in clearance of No. 1 circuit and to make appropriate recommendations.

3. To examine the performance of the remote supervisory equipment at the various control points and the remote indicating equipment at Kirkintilloch and to make appropriate recommendations.

4. To examine the time taken to recommission affected power stations and to make appropriate recommendations.

5. To examine the Board's emergency procedures with particular reference to emergency load shedding and to make appropriate recommendations.

6. To consider whether any damage to plant or equipment may have been incurred as a result of the sustained fault and to make appropriate recommendations.

7. To consider whether any damage to the public or the Board's personnel resulted from the incident and to make appropriate recommendations.

Report/

Report

The Board considered reports from all the departments and sections concerned in the incident, viewed photographic evidence of the damage and also considered reports of the effect of the incident on the H.E.B. and C.E.G.B. systems. Their report which follows has been prepared in the form first of a description of the fault as it occurred on the Strathaven-Kilmarnock/Ayr teed transformer feeder, followed by a description of events at the Grid Control Centre, the generating stations and on the H.E.B. and C.E.G.B. systems. That section of the report establishes the first objective of the Terms of Reference. Subsequent sections deal with the remaining Terms of Reference in sequence.

Report on
Strathaven-Kilmarnock Feeder Fault - November 8th, 1969

1. Transmission System Supplying Kilmarnock

Kilmarnock and Ayr are supplied from a 275 kV. double circuit, twin conductor overhead line from Strathaven Substation as shown on Fig. 1 and Fig. 2. Two 120 MVA. 275/33 kV. transformers are installed at Kilmarnock and two at Ayr. In the case of Kilmarnock, the two transformers are sited on one side of the main road through Kilmarnock and the 33 kV. switchboard is situated on the other side in a building adjacent to the power station and housing the 33 kV. switchboard, relays and control boards and the Area Distribution Control centre. The 33 kV. cables and multi-cores between the two sites pass through a cable tunnel under the road, a distance of some 220 yards.

Kilmarnock also has a 132 kV. mesh type switching station adjoining the power station with connections to the 22 kV. generation switchboard and interbus 22/11 kV. transformers supplying the distribution system.

2. History of Fault

2.1 Fault

At 03.06 on Saturday morning November 8th, 1969 during a night of wind and rain, a lightning discharge caused flashovers on both circuits of the Strathaven-Kilmarnock/Ayr double circuit, twin 0.4 sq.in. overhead line shown on the 1" to the mile map Fig. 3. It is not possible to say with certainty where the first flashovers occurred because of the subsequent damage to the line, but it is thought to have been at tower 14 where there were signs of flashovers between conductors and to earth.

There were further signs of damage between conductors on No. 1 circuit between towers 26 and 27, 41 and 42. The conductors between towers 11 and 14 on No. 1 circuit were extensively damaged and only 1 out of the 6 conductors remained in the air. It was at this point, where the line crosses the Hurlford - Galston road that a car ran into the line, skidded and overturned. The passengers fortunately only sustained minor bruises. The extent of the line damage can be seen from the photographs, Figures 4A and B.

The flashover on the No. 2 circuit was correctly cleared by the protection tripping the 275 kV. circuit breaker (H85) at Strathaven and the 33 kV. circuit breakers at Kilmarnock and at Ayr. The No. 1 circuit protective gear at Kilmarnock and at Ayr tripped the No. 1 supergrid transformer 33 kV. circuit breakers, and operated the intertrip send equipment. Unfortunately at Strathaven, although the No. 1 Kilmarnock/Ayr line main protection back-up overcurrent protection and intertrip receive relay all operated, the Reyrolle Type F trip relay failed to operate because of a defect in the hand resetting mechanism. The trip coil of the Kilmarnock/Ayr No. 1 air blast circuit breaker, H115, could not be energised by any of the protection, (except busbar protection) and the circuit breaker could only be tripped by local or remote trip push button (or supervisory control).

The lightning surge on No. 1 feeder had caused the Kilmarnock supergrid transformer Red phase co-ordinating gap to flashover, see Fig. 5A and B. Since the feeder protection failed to clear at Strathaven, the arc continued to burn and was extended by the wind to the northerly side of the busbars. Within a short time the arc had moved along the tubular busbar to the Red phase transformer bushing top cap and to the conservator or oil pipe work.

The escaping oil was ignited and the light from this and the arc could be seen over a wide area. A detail description of the transformer damage is given in Appendix I and is shown on the photographs in Fig. 6.

A passer-by saw the fire start and promptly reported it to the fire station less than a mile up the road. A fire tender was immediately sent out. An overhead linesman living nearby awoke to see the light from the fire, went out and opened the gate to the site to let the fire tender in in accordance with the local fire drill. As a result the firemen were on site within a few minutes of the start of the blaze. The Transmission Group Engineer, Mr. Scott, also came immediately to the scene and took charge of the fire fighting operations. The transformer bushings were obviously still energised as the arc was burning fiercely. Foam was used to extinguish oil fires round the tank and the base of the live bushings.

At/

At 03.09 the Distribution Control Engineer at Kilmarnock requested Grid Control to trip the Kilmarnock circuit breaker at Strathaven or if this was not possible, to make that section of the busbars dead because the supergrid transformer No. 1 was on fire.

By 03.34 the arc was reduced to small proportions and Mr. Scott was able to open the transformer isolator. The firemen then quickly extinguished the oil fires.

Details of transmission plant damage are discussed in Section 7.

Details of loads disconnected are given in Appendix II.

At Kilmarnock a partial restoration of supply was made at 04.13 by means of the 132 kV. system and local generation. The overhead line was patrolled and the No. 2 transformer and auxiliary circuits were examined. Broken conductor sections were cleared from No. 1 circuit and No. 2 circuit was re-energised from Strathaven at 14.32 hours. Supergrid T2 33 kV. circuit breakers A and B were closed at Kilmarnock at 15.19 hours thus supporting the Barony generation in supplying the Central Ayrshire 33 kV. network. At 15.53 hours the supergrid T2 33 kV. circuit breaker at Ayr was energised to support the emergency supplies being provided from the Coylton 132/33 kV. substation. All supplies were restored by 05.50. There is no doubt that the prompt action of the passer-by, fire brigade and Kilmarnock staff prevented the fault from developing into a major oil fire and considerably increasing the extent of the damage, also the duration of loss of supply.

The fault caused a major disturbance on the transmission system, loss of generation, voltage disturbance and load shedding over a wide area. These matters are dealt with in detail in subsequent sections of the report.

2.2 Fault as seen at Grid Control Centre (Appendix III)

The generation and load conditions just before the fault were -

	Demand - MW.	Generation - MW.
S.S.E.B.	1,325	1,146
Cruachan	220	-
H.E.B.	297	683
C.E.G.B.	15,094	15,404
Ffestiniog pumping	297	-
Total	17,233	17,233

S.S.E.B. import from H.E.B. - 386 MW.
from C.E.G.B. - 28 MW. (programmed float)

S.S.E.B. MVAr import from C.E.G.B. - 50 MVAr (approximately half of the MVAr gain of the Harker-Strathaven line).

The system frequency was 50.03 Hz and the system voltages at supergrid substations indicated in the control room were normal for the time.

There/

There was a senior control engineer and two assistant control engineers on duty at Kirkintilloch, while at Clyde's Mill control room there was a station control engineer and a switchboard attendant to look after the generator controls, 33 kV., 132 kV. and 275 kV. direct wire controls together with the supervisory controls for 11 grid or supergrid substations.

At 03.06 it was evident from feeder flow and other metering indications that a severe fault had occurred on the system. Indications were also received showing that the 33 kV. supergrid 120 MVA. transformer circuit breakers at Kilmarnock and at Ayr had tripped on both No. 1 and No. 2 circuits thus dropping a total of 64 MW. of load on the 33 kV. busbars at Ayr and Kilmarnock. No indication was however received of tripping of the Kilmarnock/Ayr 275 kV. feeder circuit breakers nor of any other 275 kV. circuit breakers although it was found later that H85 controlling the Strathaven-Kilmarnock/Ayr No. 2 line had opened correctly at 03.06.

System voltage indications were changing rapidly, the C.E.G.B. MVAr transfer recorder went off scale thus showing a transfer in excess of 500 MVAr. The Grid Control Centre diesel automatically took over the Grid Control Centre lighting and auxiliary supplies.

At 03.09 a message was received from Ayrshire Distribution Control requesting that the Kilmarnock/Ayr feeder circuit breaker, H115 at Strathaven be opened immediately to isolate the supergrid transformer SGT1 at Kilmarnock, as it was on fire. This was the first positive indication that the Control Engineers had of the nature of the trouble.

At about the same time they received indication of loss of generation at Cockenzie, Hunterston and of the shutting down of Cruachan.

At 03.10 Grid Control requested Clyde's Mill control to open switch H115, but they were unable to do this as the supervisory equipment would not accept the operation instructions. (As described in detail in Section 4.1 the malfunctioning of the tripping relay at Strathaven caused alarm indications to be sent continuously to the supervisory equipment at Clyde's Mill which could not therefore accept trip instructions until "indications" ceased to arrive).

Grid Control requested Clyde's Mill to continue to try to trip H115, not realising the cause of their failure to initiate the supervisory trip operation. In the meantime Clyde's Mill Control room fluorescent lighting failed due to the fall in system voltage and the emergency supply failed to come on until manually changed over.

Further information was received at Grid Control of loss of generation by S.S.E.B., H.E.B., by the A.E.A. (Chapelcross) and C.E.G.B. There were large fluctuations in the transfers with the C.E.G.B. The telephone lines were fully engaged with incoming calls from generating stations regarding the system disturbance and outside calls.

The frequency fell to 49.8 Hz and 275 kV. voltage to 200 kV. or lower, but Clyde's Mill could still not trip H115.

At 03.18 not realising the cause of the delay in switching, Grid Control instructed Clyde's Mill control to stop attempts to open H115 and instead to open the circuit breakers L50, L60 and W10 at Strathaven in/

in order to remove the infeeds to the reserve bar and hence cut off supply to the Kilmarnock/Ayr No. 1 feeder from the S.S.E.B. system.

By 03.29 it was realised that it was impossible to operate the Strathaven switchgear from Clyde's Mill supervisory equipment and Clyde's Mill were instructed to make Strathaven reserve bars dead by opening circuit breakers at Busby and Hallside, Clyde's Mill 275 kV. also at Clyde's Mill 132 kV. Substation. National Control were asked to open the Strathaven - Harker No. 1 circuit at Harker. This was all completed successfully and the fault was finally cleared by disconnecting the Harker - Strathaven No. 1 circuit at Harker at 03.34. In the meantime Leeds Control Centre had called at 03.29 for load shedding in the N.E. Region to relieve overloads on internal C.E.G.B. circuits, although some stations and control centres in Scotland had already initiated load shedding.

At 03.30 all power stations had been requested to come on load as soon as possible but at 03.34 the MW. import from C.E.G.B. had increased to over 1,000 MW. and the MVAr transfers were swinging between 400 MVAr import and 200 MVAr export.

The system voltage was rapidly rising and difficulty was experienced in controlling the voltage rise caused partly as a result of load shedding and partly because of the loss of almost all reactive power absorption by generators in Scotland. The H.E.B. also experienced high voltage as they had lost generation during the fault. Details of the operations leading to the restoration of normal system conditions by 05.15 are given in Appendix III.

A copy of the system frequency chart has been marked to show the times of disconnection and reconnection of plant and is reproduced in Fig. 7. In Fig. 8 the daily load curve for November 8th has been reproduced to show the estimated variation in demand during the fault together with generating plant capacity and output. The change in demand during the fault is difficult to ascertain because of the very large drop in voltage which affected the accuracy of some of the recorders. However the following table shows the approximate position when the maximum amount of plant was disconnected.

	Plant Disconnected	Plant Running
S.S.E.B. (including Chapelcross)	1,142 MW.	-
H.E.B.	387*	297 MW.+
Total	1,529 MW.	297 MW.
Load at 03.34 approx. S.S.E.B.	1,125 MW.	
H.E.B.	300 MW.	
	1,425 MW.	
Plant running (Scotland)	297 MW.	
	1,128 MW.ø	

* on 515 MW. of plant
\+ on 319 MW. of plant
ø error in recording could reduce by 100 MW.

Immediately/

Immediately following the clearance of the fault the all Scotland demand increased from a low level fluctuating with the varying fault conditions, to approximately 1,128 MW. shown above. (The pre-fault demand of 1,325 + 297 = 1,622 MW. reduced by shedding of approximately 324 MW. to 1,300 MW.). The H.E.B. demand of 300 MW. and generation of 297 MW. were approximately in balance and the S.S.E.B. deficit was supplied from the C.E.G.B. The provision of this 1,128 MW. of support from the C.E.G.B. was obtained as follows:-

Auxiliary gas turbines	230 MW.
Spare capacity from plant to bars	421 MW.
Loss of Ffestiniog pumping	297 MW.
Conversion of Ffestiniog to generating	180 MW.
	1,128 MW.

It was evident that during this fault the Grid Control Engineers were handicapped by the confusion caused by the lack of correct information on their diagrams and the failure to appreciate the reason why Clyde's Mill could not operate the supervisory control to disconnect Strathaven. Clyde's Mill control room staff in turn were handicapped by the failure of their emergency lighting system, the number of incoming telephone calls and, in the stress of the moment, failed for some time to appreciate the significance of the unusual supervisory indications. These matters together with the question of voltage control are dealt with in Section 4.

2.3 Operation of Generating Stations (Appendix IV)

The operation of the generating stations during the disturbance is dealt with in detail in the Generation Operations report, Appendix IV, but the main features are brought out in the following paragraphs.

The immediate effect of the fault was to draw large negative phase sequence currents from the generators feeding current into the fault. These caused the larger generators at Cockenzie, Hunterston and Blyth to trip very soon after the fault started and other machines on the S.S.E.B. and H.E.B. system followed. The Galloway Hydro Stations tripped on overcurrent or on overvoltage when the fault cleared. The H.E.B. lost from similar causes 515 MW. out of 834 MW. of plant running.

The effect of fault current in combinations with the large transfers of load and reactive power following the loss of generation near the fault, was to produce a fall in voltage over a wide area.

This fall in the 132 kV. voltage to 75 kV., the 11 kV. to 7 kV., the 3.3 kV. to 1.1 kV. caused loss of auxiliary supplies and motors to trip on overcurrent or undervoltage. Unfortunately in a number of instances "emergency" supplies for lighting and key auxiliaries were not automatically made available, the most common reason being the failure of diesel engines to be started by the automatic changeover devices which were designed to cater for a total loss of voltage. Nevertheless these diesel engines either started automatically after a delay or were available for starting manually. There were two cases of failure of emergency lighting supplies and of emergency supplies to radio links.

The persistence of the abnormally low voltage was followed by excessive system voltages (320 kV., 168 kV.) which caused damage to a number/

number of auxiliary contactors, relays and control circuits.

The voltage variations made it difficult and in some cases impossible to restart auxiliaries and later to re-synchronise until the voltage was reduced. Partly because of this the gas turbine stations at Clyde's Mill and Dunfermline were slow in starting and coming up to full load.

The starting and loading of the modern stations was slower than the older stations with 60 MW. or smaller sets. In part this was due to the checking of automatic control systems and more complex and slower run up procedures. The Hunterston Nuclear Station was slow in returning to load because of control rod indicator failures which necessitated de-pressurising 'B' reactor. The hydro stations gave a good performance apart from the remote controlled stations in Galloway where delays occurred.

2.4 Events on North of Scotland Hydro-Electric Board System (Appendix V)

The H.E.B. system was exporting 386 MW. to the S.S.E.B. at the time of the fault and remained connected throughout the ensuing disturbance. The detailed account of events on the H.E.B. system is given in Appendix V. These follow the same general pattern as on the S.S.E.B. system with loss of 515 MW. of generating plant betwen 03.06 and 03.40 hours, and a rapid restoration of plant and run up of additional plant so that between 03.25 and 05.30 hours a total of 894 MW. of generating plant was brought on load, including 200 MW. at Cruachan.

As on the S.S.E.B. system, the fault revealed a number of deficiencies in the auxiliary supply arrangements and in control and indication facilities that made it impossible to run up, synchronise and re-load sets as fast as was expected. This particularly applied to Cruachan main transformer cooling water and oil pump supplies, also to the emergency diesel starting arrangements.

Considerable difficulty was experienced in controlling the voltage on the system which dropped to very low values during the period of the fault and was made worse by loss of generation of both MW. and MVAr. When the fault was finally cleared the rise in voltage was made greater due to reduction of load by load shedding during the fault and the disconnection of generation that could have absorbed the reactive power generated by the lightly loaded transmission system.

It was suspected that two grid transformers (132/33 kV. at Lunanhead) may have been damaged due to overheating of the core and failure of core insulation to earth. After examination no defects were found in No. 1, but in No. 2 core clamping bolt insulation had failed.

Trouble was experienced in communicating between Port-na-Craig Control Centre and Kirkintilloch Grid Control via the carrier link, Cruachan - Windyhill and this added to the difficulties of the control staffs. The cause of the interference is still being investigated.

2.5 Events on C.E.G.B. System (Appendix VI)

The effect of the fault on the C.E.G.B. system is detailed in the North East Region report reproduced as Appendix VI.

The northern part of the N.E. Region experienced similar voltage

and/

and unbalanced loading conditions to Scotland but these did not extend to a marked degree into Yorkshire. The worst voltage depressions were at Blyth, Harker and Stella West 275 kV. Substations where levels fell to about 200 kV. Less severe voltage drops were experienced at other 275 kV. busbars in the area. After the fault clearance, voltages recovered to 282 kV. The distribution networks recorded voltage depressions of 32% and they also experienced high voltages in some cases for long periods because tap changer motor hand reset thermal overloads operated during the long succession of tap change operation up and down.

The negative phase sequence current and low voltage caused Nos. 2, 4, 5 and 6 sets at Blyth to be tripped. At one time the No. 6 machine was supplying zero load, 150 MVAr with alternator currents of:-

Red phase	2,000 amp.
Yellow phase	6,000 amp.
Blue phase	Off scale (meter scaled up to 12,000 amp.)

In order to reduce overloading of the 275 kV. system up the east coast, Leeds Control requested that 150 MW. of load be shed at 03.29. The N.E.E.B. were able to shed 176 MW. by 03.56; of this 110 MW. was shed in 6 minutes.

3. To investigate the reasons for the delay in clearance of No. 1 circuit and to make appropriate recommendations

3.1 Performance of Protection (Appendix VII)

The two Strathaven - Kilmarnock/Ayr feeders are protected at Strathaven by Reyrolle type H distance protection, overcurrent protection and an intertrip receive relay operated over P.O. pilots to Kilmarnock and private pilot cables Kilmarnock to Ayr.

Most of the other lines connected to the Strathaven Substation are protected by pilot wire protection. The Strathaven - Harker circuits are however protected by carrier lock-in protection at Strathaven, with carrier lock-in and also distance protection at Harker. The Neilston - Strathaven circuit is protected by distance protection.

The policy of the Board regarding the fitting of main protection had been progressively modified as the Supergrid developed. First one set of main protection and overcurrent protection was provided on each circuit together with standby overcurrent and earth fault protection which could be brought into service if the main protection became faulty. Later as the system developed, it was agreed to provide two sets of main protection on new circuits and on existing circuits whenever modifications had to be made for other reasons. In 1968 it had been agreed to hasten the process and to draw up a programme for providing two sets of main protection throughout the Supergrid by the winter 1972/73. No second main protection had as yet been installed on any feeders around Strathaven.

The details of the protection and the sequence of relay operations is given in Appendix VII.

It is clear from an examination of the relay flag indications that on the No. 1 circuit the distance protection, overcurrent protection and intertrip receive relays all operated correctly, but that the type F tripping relay did not operate. An examination of the relay showed that this was due to the extension arm of the hand reset feature becoming distorted and holding the normally closed "cut-throat" contact in the relay tripping coil circuit permanently open and thus making the relay inoperative. It was therefore impossible for any of the protection (except the busbar protection) to trip the circuit breaker.

The maximum value of the fault current in the Strathaven-Kilmarnock feeder is estimated to have been 6,000 amps. for the phase-phase-earth fault. The current through the bus coupler is estimated to have been 2,340 amps. during the initial transient period of the fault, falling to a value of the order of 1,300 amps. after a period of the order of 2 seconds. Fig. 1 in the Appendix VII shows the distribution of fault current in this latter condition. The overcurrent relay on the bus coupler is set at 2,000 amps. and should start to operate at 2,600 amps. and therefore would not operate during the early stages of the fault.

At 03.29 the Busby and Neilston infeeds to Strathaven were disconnected. Attempts have been made to calculate the fault currents in the changing fault conditions but the resulting fault current distributions do not explain the tripping by overcurrent protection at 03.32 of the bus coupler and Wishaw No. 2 circuit breakers at Strathaven. This matter is therefore still being investigated.

3.2/

3.2 Conclusions

The primary cause of the delay in clearing the fault was the defective tripping relay and a contributory factor was that in accordance with present standard protective schemes, the overcurrent relays operate through the main tripping relay and not direct. Other contributory factors dealt with in later sections were the defect in the supervisory system which prevented its use to trip the Strathaven circuit breakers.

The Board of Inquiry noted that the possibility of defective Reyrolle type F tripping relays was dealt with in the C.E.G.B. Transmission Design Circular No. 344 dated October 7th, 1969. This document was only received by the Protection Section on or about 25th October, 1969 but it was clear that this defect was known to the C.E.G.B. for some time prior to the issue of the Circular. The latter described the following three courses of action:-

(a) The relay may be inspected and adjusted.

(b) On relays which may be both hand or electrically reset, the hand-reset mechanism may be removed.

(c) The hand-reset mechanism may be changed for an improved design which the manufacturer now has available.

The Protection Section had decided that the only satisfactory solution was the adoption of the remedy involving the fitting of the new components and were in the process of determining the extent of the work involved when the fault occurred.

3.3 Recommendations

The Board of Inquiry makes the following recommendations regarding protective equipment.

(a) That existing arrangements for a second set of main protection to be installed throughout the 275 kV. system be expedited as a matter of urgency and that pending this, the overcurrent protection be reconnected to trip directly or through a second trip relay. (By December 12th all overcurrent relays on the 275 kV. system were connected to trip directly).

(b) That arrangements be made between the C.E.G.B. the S.S.E.B. and H.E.B., to ensure that any information regarding the maloperation of protective gear which may affect security of supplies or safety should be interchanged as soon as possible without awaiting the circulation of the final T.D. Circular. (Arrangements have now been made between the Boards for rapid circulation of any such information).

(c) That the condition of tripping relays on the 275 kV. and 132 kV. systems and in generating stations be reviewed and that as a matter of urgency they be modified where appropriate in accordance with the recommendations of T.D.C. No. 344. Also that the Areas/

Areas be advised to examine the tripping relays on the distribution system and modify as appropriate. (The reset knobs on the 275 kV. system were removed by November 9th, 1969; 132 kV. system and generating station trip relays were checked and modified as appropriate by December 4th, 1969. The Areas were given copies of T.D.C. No. 344 by November 20th, 1969).

(d) That consideration be given by the H.E.B. to the provision of duplicate protection on the Tealing - Westfield and the Dalmally - Windyhill circuits. (A second set of main protection is on order for each circuit).

(e) That consideration be given at the System Design Committee to the provision of improved forms of back-up protection on the supergrid. (A preliminary paper setting out proposals was discussed at the December S.S.E.B. System Design meeting and they are to be developed as a matter of urgency).

4. To examine the performance of the remote supervisory equipment at the various control points and the remote indicating equipment at Kirkintilloch and to make appropriate recommendations

4.1 Supervisory control equipment and general indication at Kirkintilloch (Appendix VIII)

The Strathaven 275 kV. Substation together with 11 other supergrid and grid substations are controlled from Clyde's Mill Power Station control room where supervisory control equipments are installed. These equipments include facilities for alarm and indication of operations on the 33 kV. distribution feeders at some of the substations in accordance with the S.S.E.B. Transmission Design Memorandum SS26 (Rev. 1), of which a copy is reproduced as Appendix XI of this report.

The Grid Control engineers were aware at 03.06, from indications on the G.I. equipment, that the fault on the Strathaven - Kilmarnock/Ayr feeder had been cleared on the 33 kV. side of the transformers. No indications were received from Strathaven and it was assumed that both the No. 1 and No. 2 feeder circuit breakers, H115 and H85 had not tripped, though in fact H85 had tripped correctly. Clyde's Mill should also have been aware of the conditions from alarm indications on the supervisory equipment. Grid Control should have been able to instruct Clyde's Mill to trip the 275 kV. circuit breakers at Strathaven but because of a defect in the supervisory neither Grid Control nor Clyde's Mill had the information and the facilities necessary.

The detail description of the fault in the supervisory equipment and the proposed remedies are given in Appendix VIII. Briefly, the operation of the protection on the No. 1 circuit breaker H115 should have given a fleeting alarm indication to the supervisory equipment since the protection relays normally reset within a few milli-seconds of the clearance of the fault. The supervisory equipment takes several seconds for a complete scan of indicating relays and must therefore store the information on a self locking relay until the indications can be transmitted. On equipment of G.E.Co. manufacture these storage relays are self resetting at the end of the scanning period. Due to the fault being sustained and consequent failure of the protection relays to reset, a persistent condition was applied to the supervisory equipment which resulted in the indicating relay re-operating after each scan thus causing continuous transmission.

The standard S.S.E.B. (and C.E.G.B.) specification for remote control equipment stipulates that incoming indications should take priority over control functions with the result that it was impossible for the Clyde's Mill operator to trip any circuit breaker at Strathaven. The G.E.Co., equipment at Clyde's Mill and about 25 other equipments installed on the S.S.E.B. system are the only type which have this particular defect. S.T. & C. and Plessey (A.T. & C. Co.) equipments having accepted an indication do not transmit the same indication again until relays are reset from the control end and hence would have allowed the trip operations to have been carried out.

The G.I. indications from Strathaven to Kirkintilloch are transmitted by the supervisory equipment to Clyde's Mill where they are repeated to Kirkintilloch. The Grid Control engineers did not receive intelligible indications during the initial period of the fault due to the "lock-up" on the supervisory.

The/

The temporary failure of the emergency lighting system at Clyde's Mill, contributed towards the delay in the use of other supervisory panels to clear all infeeds into the faulty section of Strathaven.

4.2 Communication System (Appendix VIII)

Detailed comments on the performance of the communication system as it affected the Grid Control staff, the Telecommunication Section and the Power Station staff are contained in Appendix VIII.

Difficulties were experience in maintaining communication between Kirkintilloch Grid Control and Cruachan, and also between Port-na-Craig Control Centre and Cruachan via Windyhill. Communication for both parties is normally via the carrier link between Windyhill and Cruachan. Investigation has shown that the difficulty was not caused by corona discharge but by some, as yet unidentified, defect. The G.P.O. circuits offered as an alternative were of poor quality. It was agreed that in view of the importance of maintaining a good quality communication link between control centres, an underground circuit be hired annually from the G.P.O. The hire of this line could be reviewed annually in the light of experience with the present carrier link.

The new control centre will be equipped with a facility for simultaneous communication to all power stations (and Area Control Centres). This should overcome some of the difficulties experienced in the control centre due to large numbers of incoming calls from stations asking for information or instructions concerning the system disturbance and should enable the station and area control staff to make a better assessment of the part they are to play in dealing with a system disturbance.

As a result of the power failures it was discovered that the radio transmitters between some power stations and Grid Control depend upon a.c. supplies for their operation. During the system disturbance these supplies were either disconnected or the voltage was so low that the transmitters would not have operated had they been required to do so. It was agreed that it was most desirable that these transmitters be independent of a.c. supplies from the system.

4.3 Recommendations

The Board of Inquiry therefore made the following recommendations:-

Supervisory Equipment

(a) That agreement be reached as soon as possible with the G.E.Co. as to the means to be adopted on existing equipments to prevent incoming alarm and indications from inhibiting control functions, if need be by adding an override feature.

(Discussion of possible schemes is already taking place and as soon as a practicable scheme is found, an equipment will be modified and tested prior to modification of all equipments. In the meantime steps are being taken to acquaint all supervisory equipment control personnel with this feature).

(b)/

(b) That it is most desirable that operation functions should not be inhibited by alarm and indication functions. The revision of the national specification should be discussed with the C.E.G.B. with the object of ensuring that in future equipments the operator will always be able to carry out control functions, if necessary, by providing an override feature.

(c) That General Indications to the Grid Control Centre for major 400 and 275 kV. substations be transmitted independently of any supervisory control multicores and equipment. It was agreed that the indications from minor supergrid substations or grid substations could be transmitted to a major substation and thence with the major substation G.I. indications and metering to Grid Control.

(The necessary equipment is already on order for the transmission of G.I. indications to the New Control Centre).

(d) That consideration be given to improving the training of the appropriate personnel in the use of supervisory control equipments and interpretation of indications and alarms, including practice in equipment use.

(Arrangements have been made for this subject to be discussed with Station Managers and Area Engineers).

Communication Equipment

(e) That an underground circuit be rented from the G.P.O. between Kirkintilloch Grid Control Centre and Cruachan at a cost of approximately £1,000/annum.

(f) That all radio transmitters and receivers for communication between Grid Control and power stations, transmission section offices and Area Distribution Control Centres be made independent of a.c. supplies from the transmission or distribution system.

(g) That the G.P.O. be asked to modify the Telephone Directory to indicate that the Kirkintilloch Grid Control number is only available during office hours.

(h) That, pending the move to the new control centre, the Telecommunications Section should investigate the provision of some means of making accouncements simultaneously to all power stations and Area Distribution Control Centres (also transmission control centres such as Neilston and Windyhill).

5. To examine the time taken to recommission affected power stations and to make appropriate recommendations

5.1

The effect of the system disturbance on the operation of the power stations has already been described in Section 2.3 and in detail in Appendix IV.

The persistence of the fault with the resulting very large fall in system voltage made it difficult for operators to decide upon the correct action to take particularly as in some instances they also had incorrect frequency indications arising from low system voltages. It was also difficult to communicate with Grid Control because the telephone network was overloaded. The severity of the fault was such that in some cases operators thought the fault must be close to their station. The station staffs would have been in a better position to help to control the disturbance had Grid Control been able to make a general statement of all control rooms and this is referred to in Section 4.3 (h).

The Board of Inquiry therefore accepted the proposal made by the Chief Engineer Generation Operation for a detailed examination of the power stations under the conditions of this system fault and other emergencies. It was agreed that the findings would be made the subject of a joint meeting to which the C.E.G.B. and H.E.B. would be invited.

5.2 Recommendations

The Board of Inquiry therefore made the following recommendations:-

(a) That the Generation Operation Department make a detailed examination of the operation of the power stations under the conditions of this system fault and other emergencies. Also that the findings be made the subject of a joint meeting with C.E.G.B. and H.E.B. and members of the Board of Inquiry.

(b) That frequency recorders and indication instruments in power stations, transmission and area distribution control rooms be checked to see that they give correct frequency indication independent of voltage. Where necessary the existing instruments should be replaced.

(Instructions have been given to the Metering Section of the Transmission/Distribution Division in co-operation with the other Divisions concerned, to prepare proposals for the purchase of any new instruments required).

6. To examine the Board's emergency procedures with particular reference to emergency load shedding and to make appropriate recommendations

6.1

The Board's emergency load shedding procedures are set down in documents D.I.9/1, of which copies are reproduced as Appendix X. These procedures rely for their initiation on instructions from Grid Control being communicated to the power stations, transmission control centres and Area Distribution Control Centres. Load shedding can also be initiated locally if frequency commences to fall rapidly and a 20% load shed is automatically started by frequency relays set at 48.5 cycles with a second 30% stage set at 48 cycles.

There was some confusion caused by incorrect frequency indication due to the senstivity of some instruments to voltage. An instruction to Distribution Control Centres to shed 50% load (i.e. 560 MW.) was given at 03.35 by Grid Control, and 200 MW. was actually shed by 03.45. Details of load shedding by the Areas are given in Appendix II.

The Board of Inquiry noted that Leeds Control requested the N.E.E.B. at 03.29 to shed 150 MW. The C.E.G.B. report, Appendix VI, shows that 110 MW. was shed in 6 minutes.

6.2 Recommendations

The Board of Inquiry therefore made the following recommendation:-

(a) That the Chief Engineer Generation Operation should arrange to review the operation of the S.S.E.B. load shedding procedures with a view to improving the speed of response to Grid Control requests. To this end S.S.E.B. representatives should visit the N.E. Region to acquaint themselves of the arrangements of the Region and the N.E.E.B. for emergency load reduction.

7. To consider whether any damage to plant or equipment may have been incurred as a result of the sustained fault and to make appropriate recommendations

7.1 Plant or equipment owned by the Board

Considering first plant directly involved in the fault. The transformer damage is described in the Plant Design Engineer's report - Appendix I. The damage appears to have been confined to the Red phase bushing and some oil pipework and the conservator, together with some consequential damage to instruments. The transformer was repaired on site and returned to service on December 15th, 1969. It is considered that arcing horns should not be provided on transformer bushing unless they can be designed to keep the arc well away from the bushing. When co-ordinating gaps are provided in accordance with standard practice near to the transformer, arcing horns should be removed from the transformer H.V. bushings.

The stray earth fault currents damaged multicore cables in spite of the bonding and earthing of the substation. Some of the damage to multicores between the transforming station site and the 33 kV. switch-house across the Kilmarnock - Ayr road was due to there being no metallic connection between the two sites. This is now being provided.

The damage to the overhead line towers and conductors illustrated by the photographs was in no way unusual for a fault lasting for over 25 minutes. The mechanical strength of the earth wire and conductors not otherwise damaged by arcing was not materially reduced by the prolonged passage of fault current. Some tower cross-arm steelwork was damaged by arcing and had to be replaced.

The isolators and circuit breakers at Strathaven which carried fault current for 20 minutes were not damaged.

Considering now the effect of the negative phase sequence fault current on machines, it is possible that the rotors of the 300 MW. sets at Cockenzie may show signs of overheating around the ends of the slots machined transversely in the rotors to produce comparable quadrature axis transverse stiffness. The English Electric Co. have already advised the reduction of the negative phase sequence alarm setting from an I^2t of 7 to 2. It is considered that none of the other sets in Scotland will have suffered any damage on this account.

The damage to plant caused by the excessive fall in voltage and then rise in voltage after the fault cleared, is difficult to assess as some damage may not have been sufficient to cause immediate failure of plant. The generating stations experienced the following damage:-

Burnt out contactors, trip coils and fuses at Braehead and Cockenzie.

Burnt out a.c. contactors at Carolina Port "B" of H.E.B.

On the transmission system both 132/33 kV. 30 MVA. transformers at H.E.B. Lunanhead were suspected of failure of insulation between core and earth due to over-excitation. After examination no defects were found in No. 1, but in No.2 core clamping bolt insulation had failed. Also/

Also in the N.E.E.B. and H.E.B. systems as automatic tap changing equipment had operated to correct the low voltage, there was an excessively high voltage when the fault was cleared. In a number of cases the continuous succession of tap operations caused the tap changer motor thermal overload protection to operate and prevent further tap changing with the result that excessive voltage was experienced till the thermal overload relays had been reset. In other cases tap changers got out of step and locked out with similar effect on voltage.

7.2 Damage to plant on consumers systems (Appendix IX)

It is to be expected that with a fault of this nature there would be damage to consumers plant and equipment due to overheating during the long period of low voltage and unbalanced loading before the fault was cleared, or due to the effects of the very high voltages experienced in some parts of the system. Correct operation of no-voltage protection and overload protection would protect most equipments. Damage would also be expected in continuous process plants due to complete loss of supply.

Fortunately on Saturday morning at 3 a.m. the load is very low and many industrial plants were shut down. So far reports of damage or interruption to process plant have been received as follows:-

Ravenscraig (Colvilles) lost 275 kV. supply at 03.06 hours* and generator 4 tripped. Generators 1, 2 and 3 tripped at 03.30 hours, resynchronised at 07.30 hours.

* 33 kV. circuit breakers were opened by hand by Colvilles because of excessively low voltage.

British Petroleum (Grangemouth) lost 5 generators through low voltage.

Nairns (Kirkcaldy) lost 2 generators.

Damage to other plant has been notified to the Areas as listed in Appendix IX.

The H.E.B. report a number of domestic off-peak heater elements damaged in Peterhead area, also a Decca radar equipment. A number of industrial motors were damaged in the Dundee area.

7.3 Recommendations

(a) That during the annual overhaul the rotors of the Cockenzie machines be examined for damage by negative phase sequence current.

(b) That a check be made on the design of arcing horns fitted to supergrid and grid transformer 275 and 132 kV. bushings, and that where co-ordinating gaps are provided near the transformer, any arcing horns on the bushings be removed.

(c) That a check be made to ensure that earthing systems on transformer station sites are adequately bonded to earthing systems of nearby plant, relay and control buildings or distribution substations, with which there is cable or multicore interconnection.

(d)/

(d) That the System Design Committee should investigate the problem of voltage control during and after faults have been cleared and make recommendations for implementing their findings.

(e) That the Area Distribution Control Centre Committee should review the provision of recording voltmeters in the distribution control centres and make arrangements to supplement these, if considered necessary.

8. To consider whether any damage to the public or the Board's personnel resulted from the incident and to make appropriate recommendations

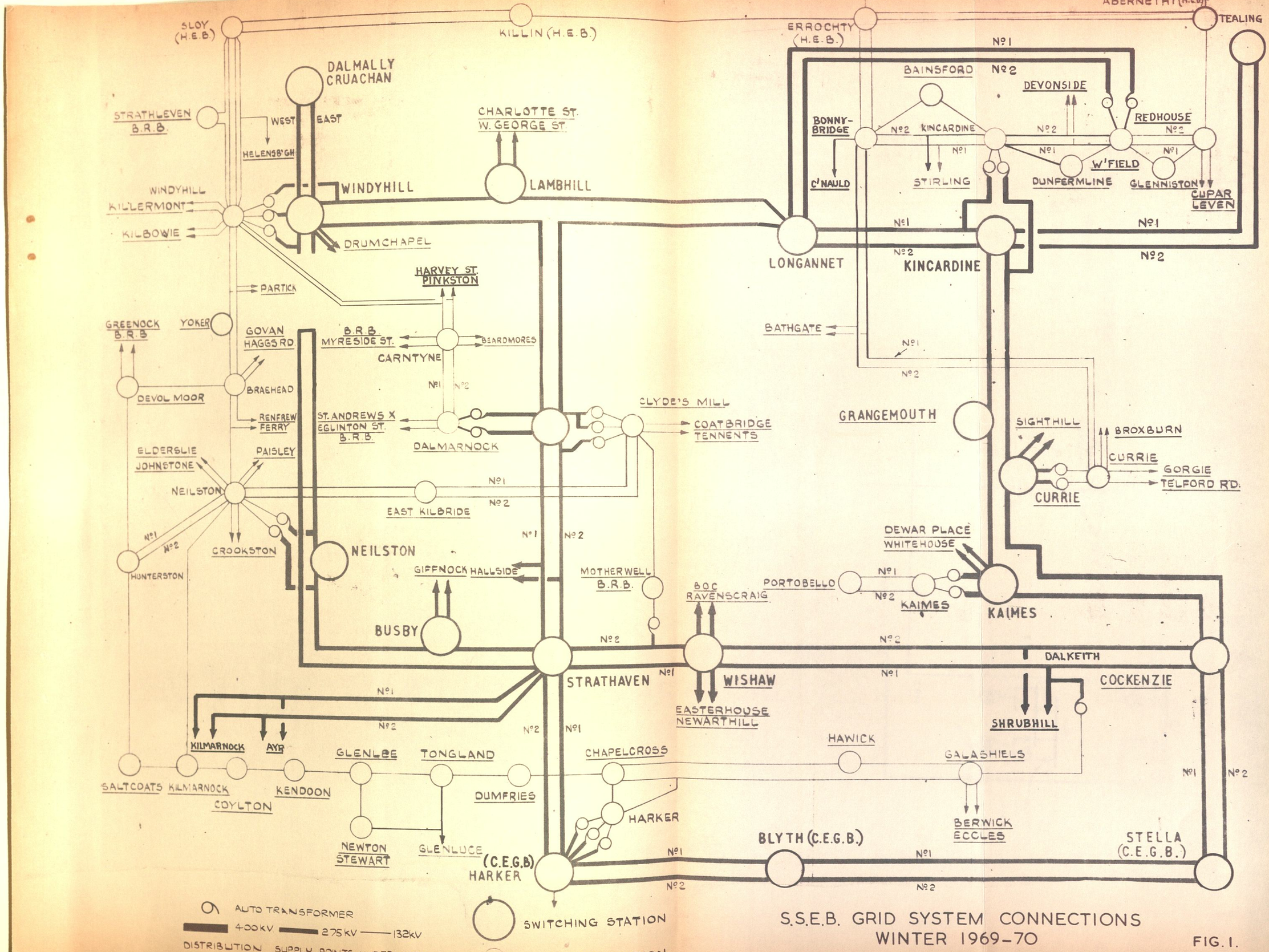
8.1

The incidents that occurred during the fault and immediately after its clearance were reviewed by the Board of Inquiry to see if there were any cases of danger to the public or Board personnel. The breaking of the overhead line conductor was a hazard, and the provision of direct tripping from the overcurrent protection, pending the installation of a second trip relay and a second set of main protection, reduces the hazard as far as practicable.

The protective gear modifications also reduce any abnormal hazard that may have existed due to the slow clearance of a fault on the system.

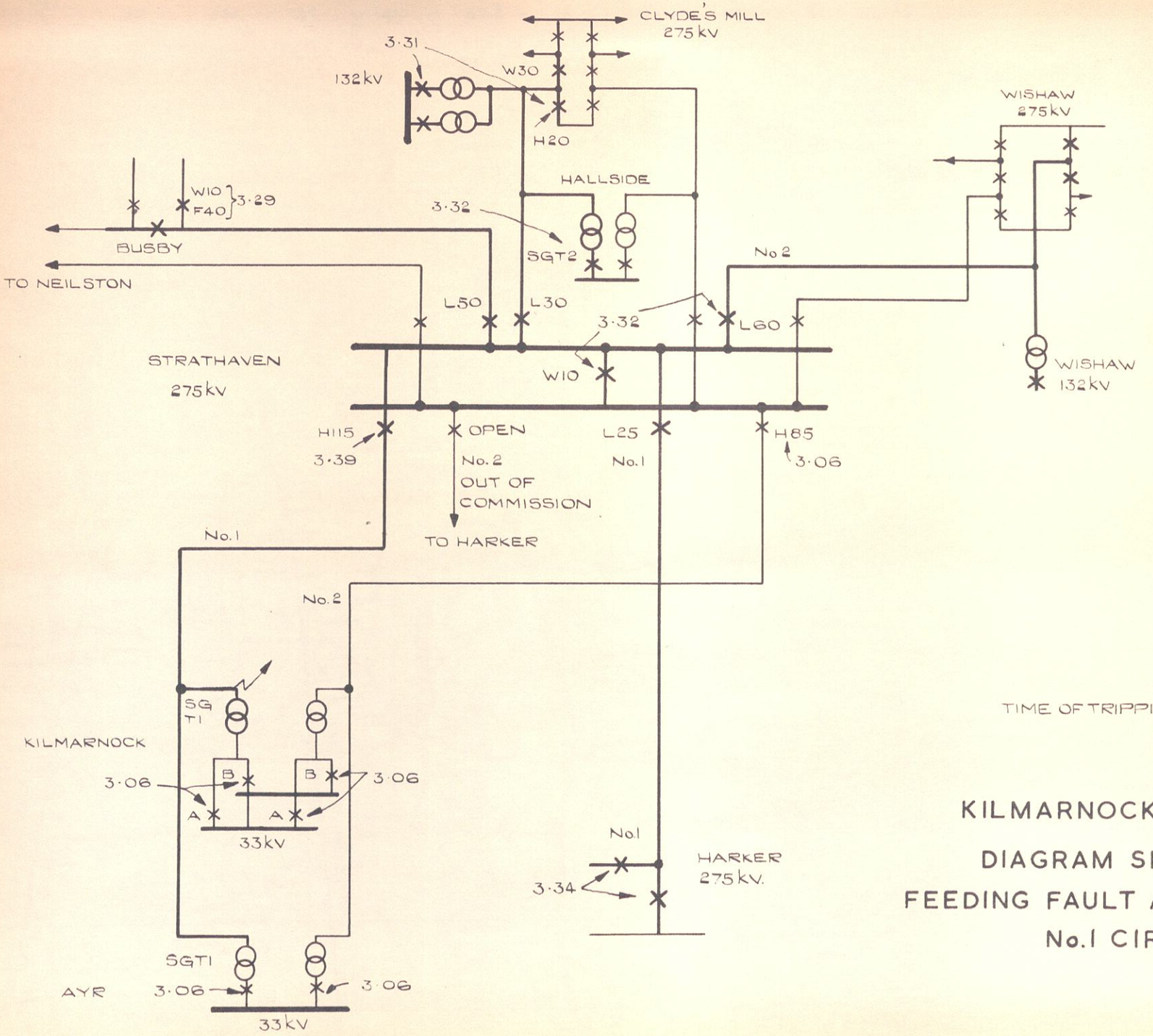
8.2 Recommendation

The Board of Inquiry recommend that the provision of duplicate main protection as proposed in Section 3.3 of the report be completed if at all possible by the winter of 1970/71. Also that the modification to the supervisory equipments proposed in Section 4.4 be completed as soon as possible.



S.S.E.B. GRID SYSTEM CONNECTIONS WINTER 1969–70

FIG. 1.
SK. 4082



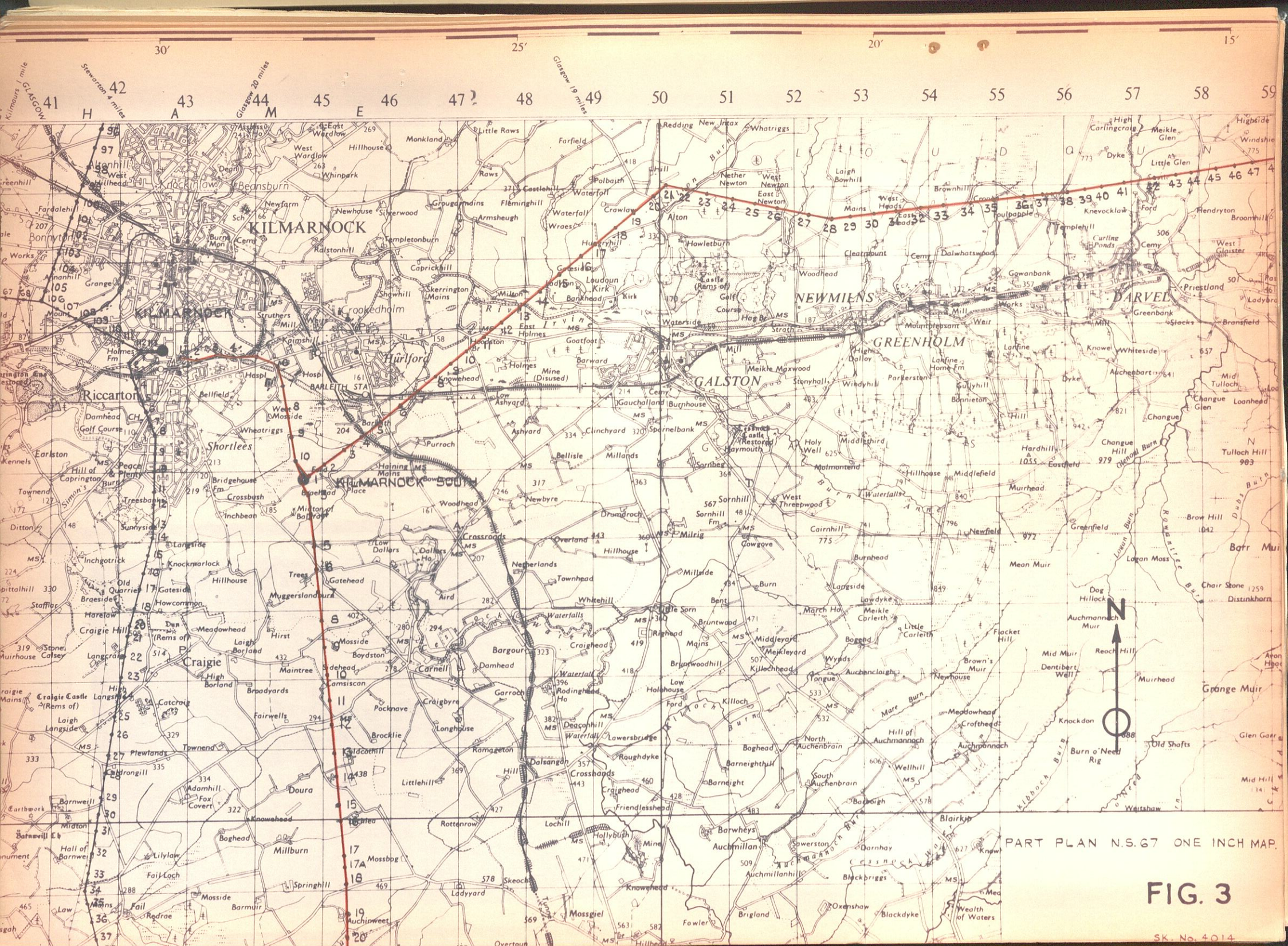
TIME OF TRIPPING SHOWN THUS - 3·32

KILMARNOCK FAULT NOV. 8 1969

DIAGRAM SHOWING CIRCUITS FEEDING FAULT AFTER CLEARANCE OF No.1 CIRCUIT AT 3·06

FIG. 2

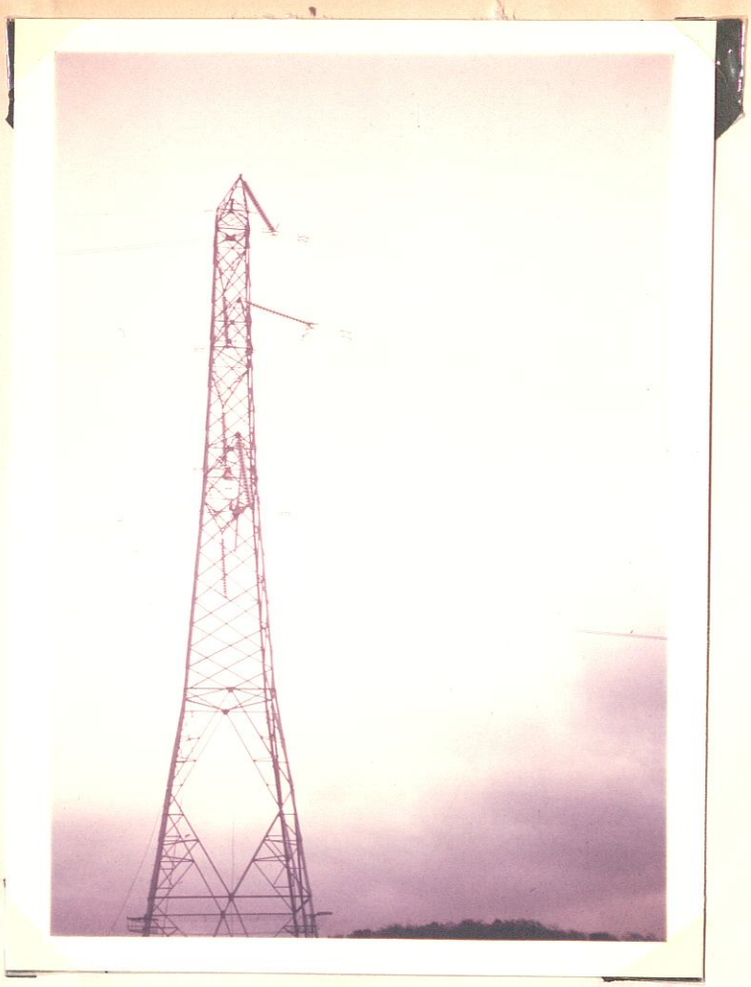
SK 4021



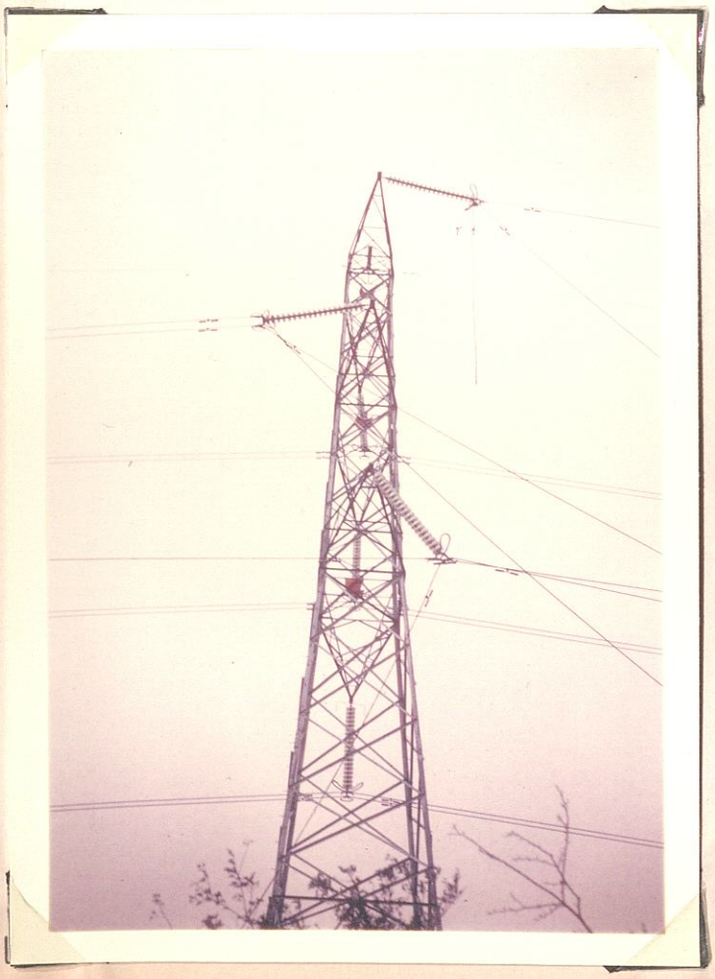
PART PLAN N.S. 67 ONE INCH MAP.

FIG. 3

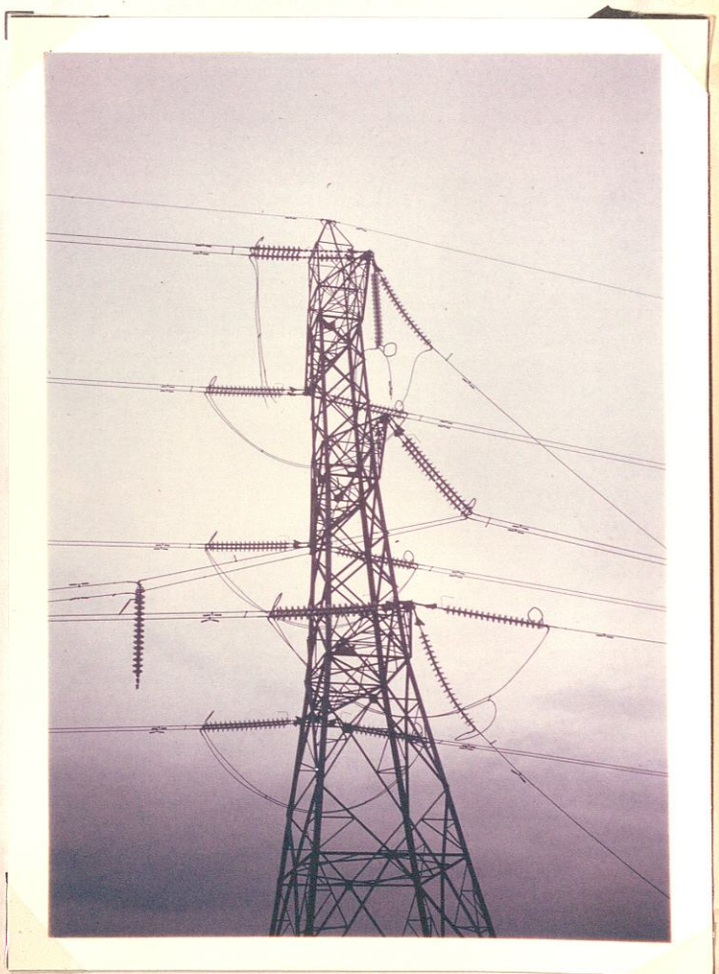
SK. No. 4014



TOWER No.11



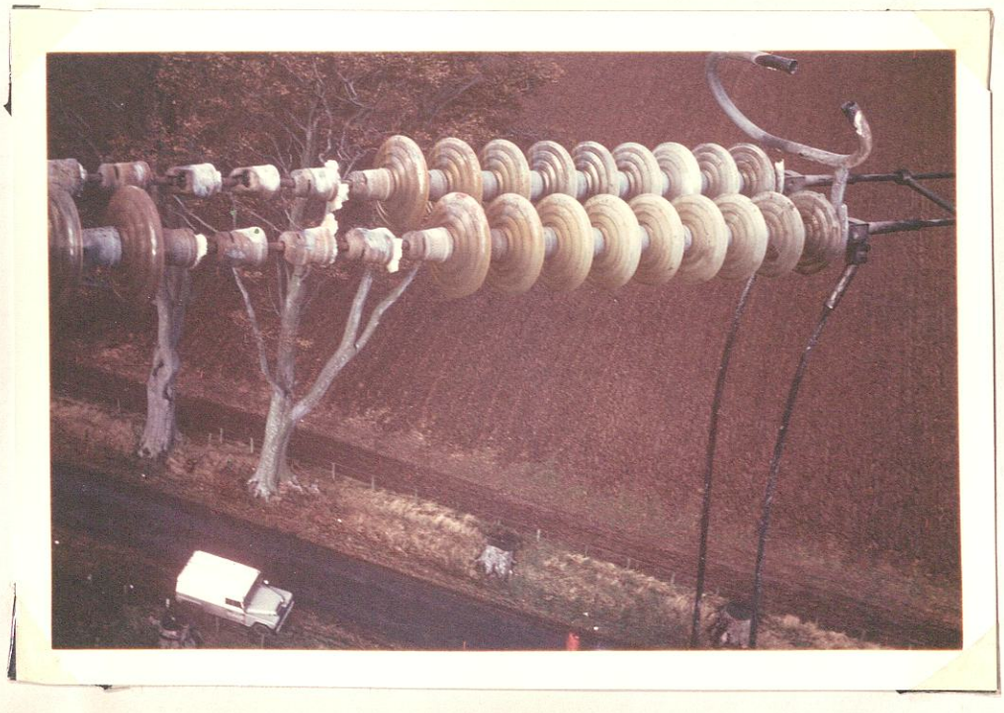
TOWER No.13



TOWER No.14

FIG.4A.

TOWER Nos. 13 & 12
EARTH WIRE SUSPENSION CLAMP DAMAGE



TOWER No. 14
TOP PHASE INSULATOR STRING
STRATHAVEN SIDE

FIG. 4B

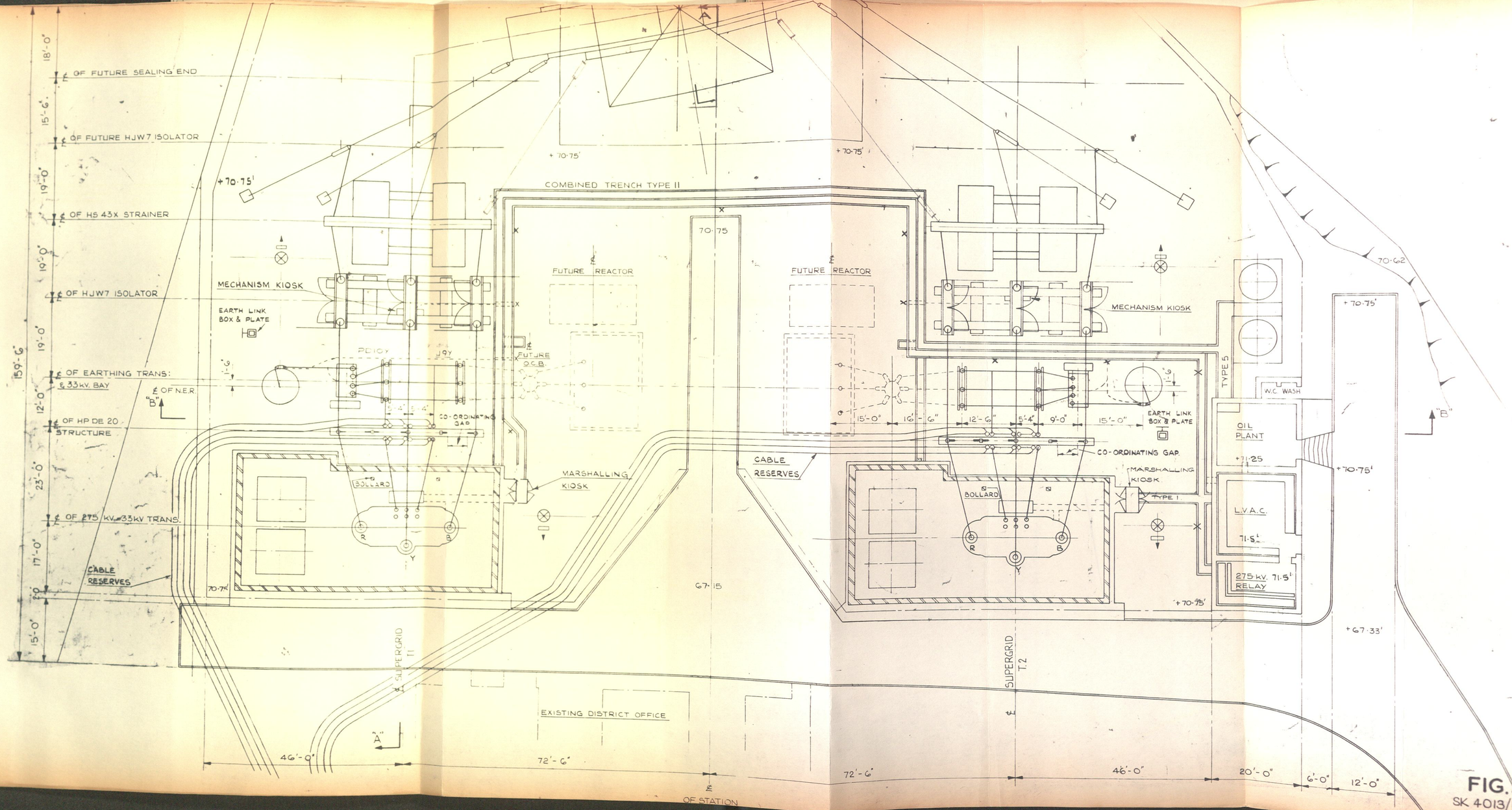
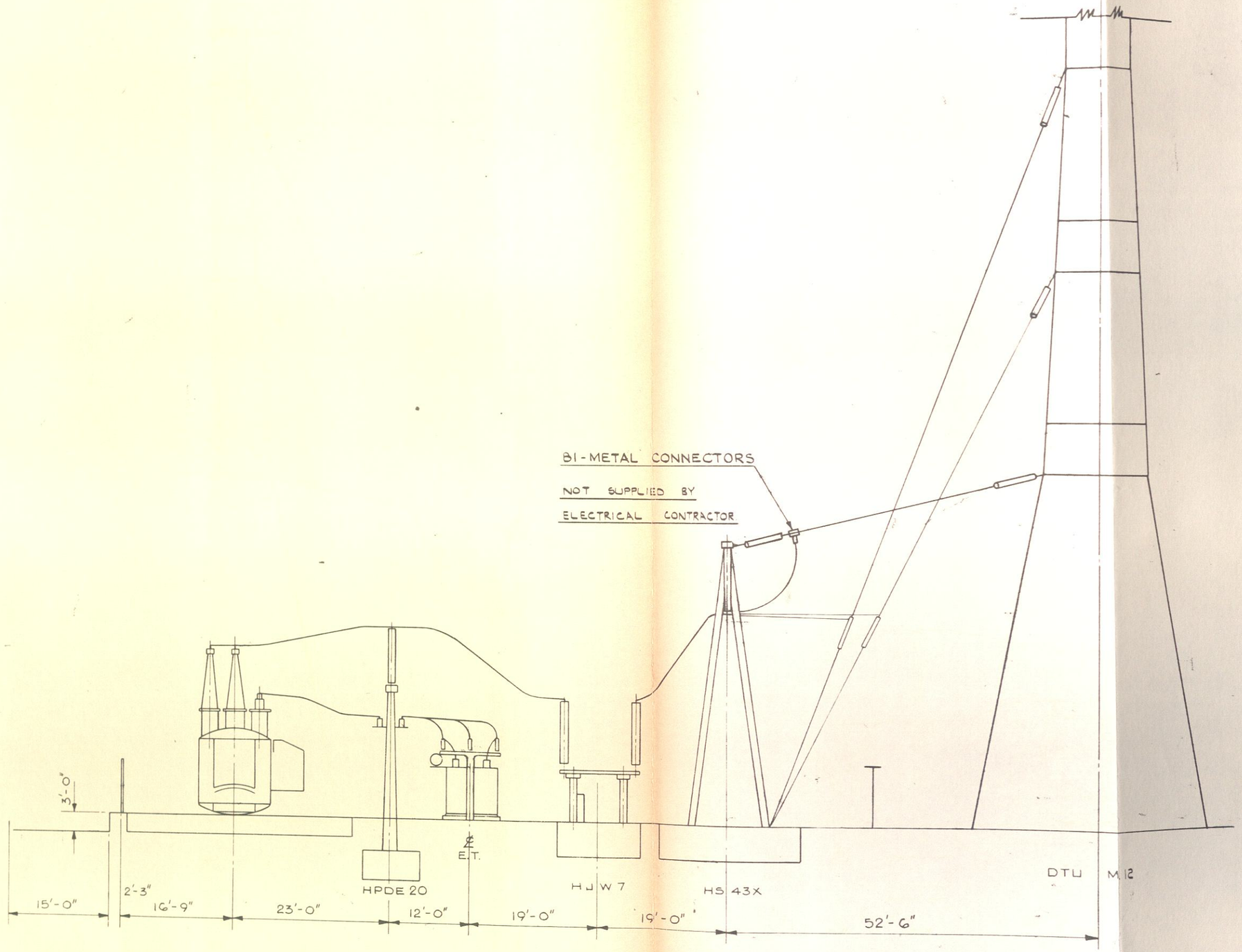


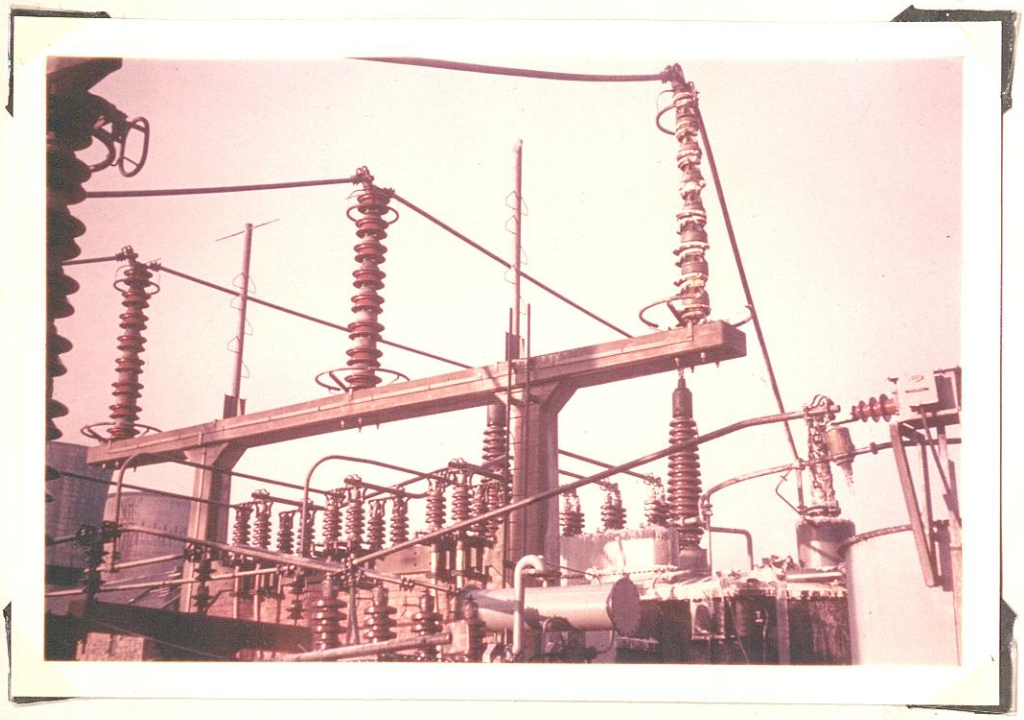
FIG.5A.
SK 4013/1



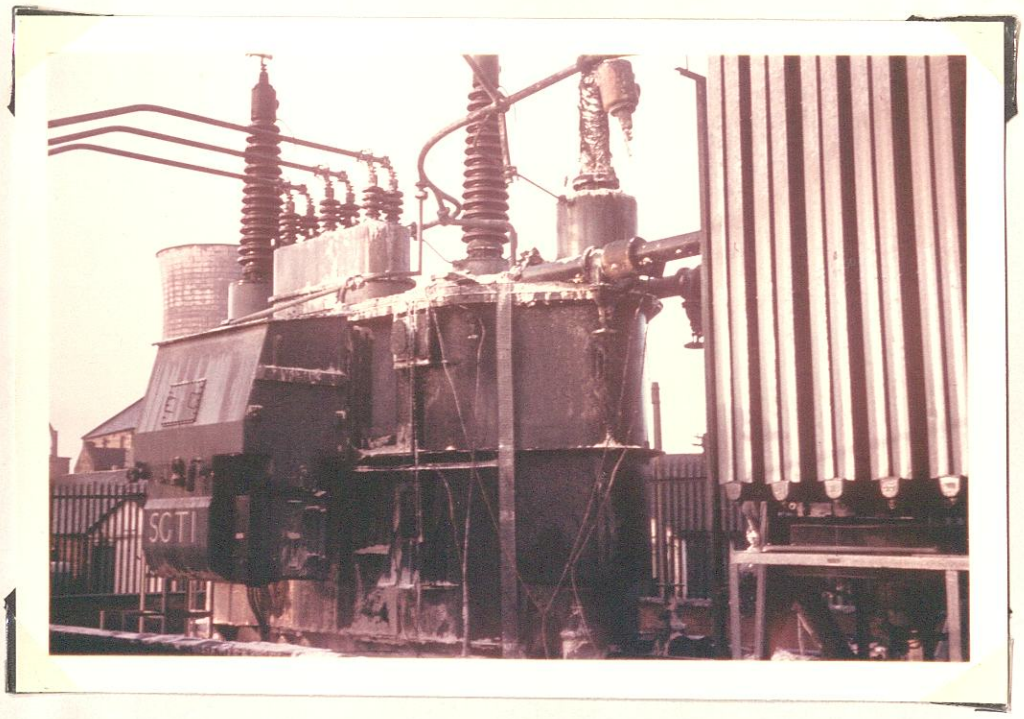
SECTION "AA"

FIG. 5B.

SK 4013/2



DAMAGE TO CO-ORDINATING GAP &
TO STACK OF STATION POST INSULATORS



DAMAGE TO RED PHASE
275 kV BUSHING & TO BUSBAR

FIG. 6

APPENDIX 1
SYSTEM FREQUENCY

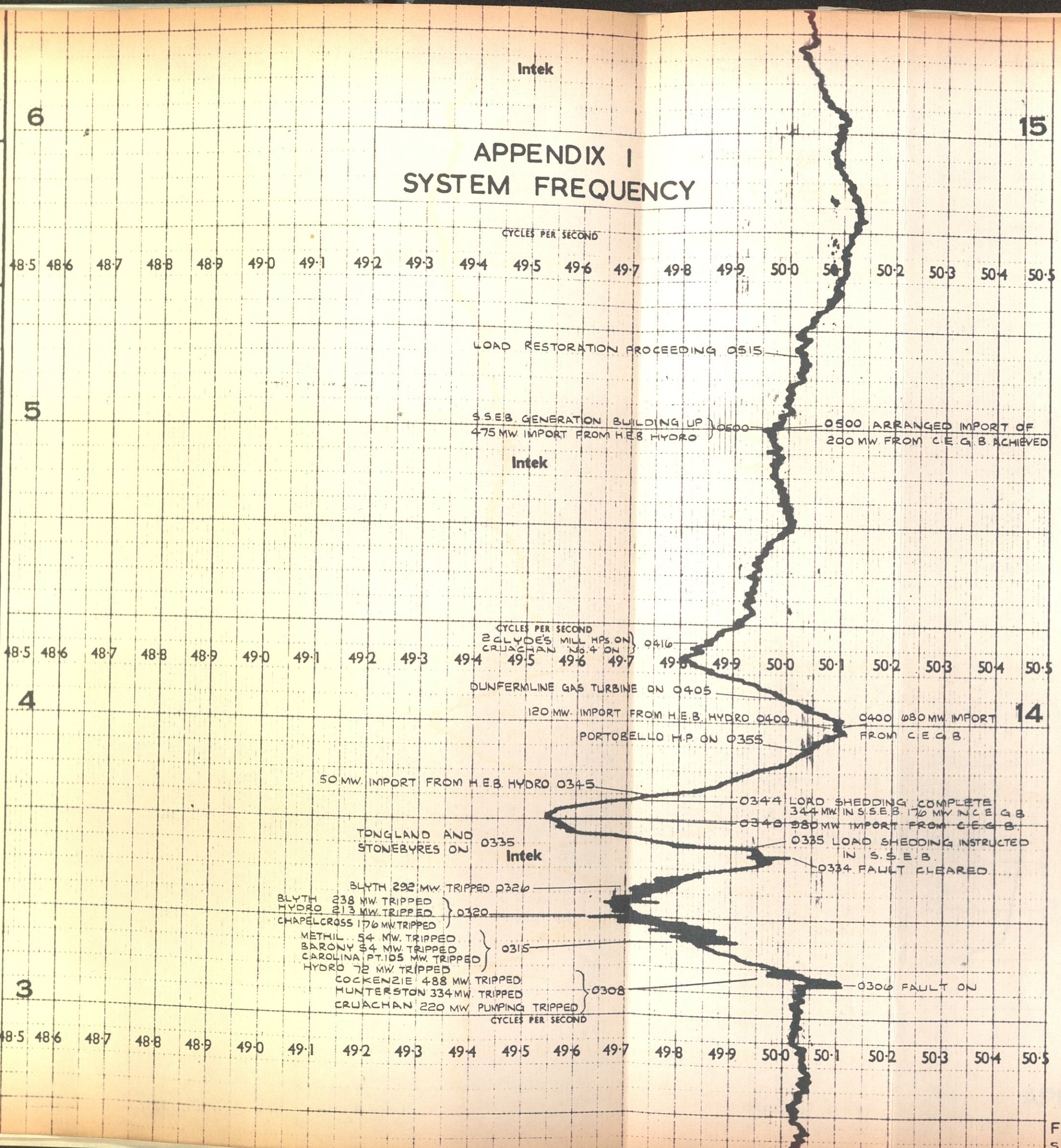

Intek
6
15
CYCLES PER SECOND
48·5 48·6 48·7 48·8 48·9 49·0 49·1 49·2 49·3 49·4 49·5 49·6 49·7 49·8 49·9 50·0 50·1 50·2 50·3 50·4 50·5
LOAD RESTORATION PROCEEDING 0515
5
S.S.E.B. GENERATION BUILDING UP 475 MW IMPORT FROM H.E.B HYDRO
0500
0500 ARRANGED IMPORT OF 200 MW FROM C.E.G.B ACHIEVED
Intek
CYCLES PER SECOND
2 CLYDE'S MILL HPs ON
CRUACHAN No.4 ON
0416
DUNFERMLINE GAS TURBINE ON 0405
4
14
120 MW. IMPORT FROM H.E.B. HYDRO 0400
0400 680 MW IMPORT FROM C.E.G.B
PORTOBELLO H.P ON 0355
50 MW. IMPORT FROM H.E.B. HYDRO 0345
0344 LOAD SHEDDING COMPLETE 344 MW IN S.S.E.B. 176 MW IN C.E.G.B.
0340 680 MW IMPORT FROM C.E.G.B.
TONGLAND AND STONEBYRES ON 0335
0335 LOAD SHEDDING INSTRUCTED IN S.S.E.B.
0334 FAULT CLEARED
Intek
BLYTH 292 MW TRIPPED 0326
BLYTH 238 MW TRIPPED
HYDRO 213 MW TRIPPED
CHAPELCROSS 176 MW TRIPPED
0320
METHIL 54 MW TRIPPED
BARONY 54 MW TRIPPED
CAROLINA PT. 105 MW TRIPPED
HYDRO 72 MW TRIPPED
0315
3
COCKENZIE 488 MW TRIPPED
HUNTERSTON 334 MW TRIPPED
CRUACHAN 220 MW PUMPING TRIPPED
0308
0306 FAULT ON
CYCLES PER SECOND
48·5 48·6 48·7 48·8 48·9 49·0 49·1 49·2 49·3 49·4 49·5 49·6 49·7 49·8 49·9 50·0 50·1 50·2 50·3 50·4 50·5

FIG. 7
SK.4083

RHB/305/1024 377231-054C

4/69

8.
11

KILMARNOCK FAULT - SAT. 8th. NOV. 1969

ESTIMATED REDUCTION IN DEMAND DUE TO LOW VOLTAGE AND LOAD SHEDDING.

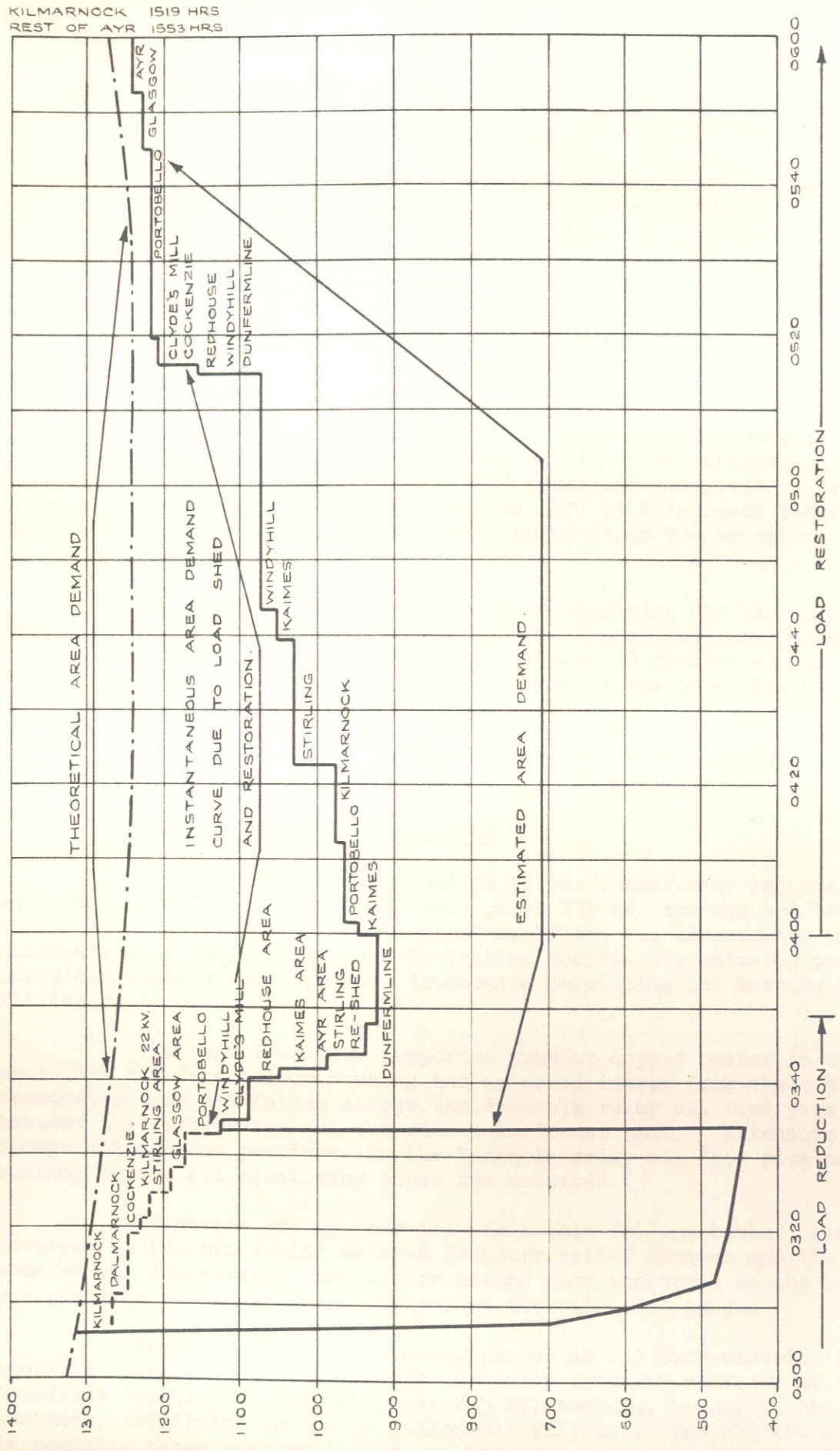


FIG. 8.

APPENDIX II

SK 4081

APPENDIX I

275 kV. System Fault - November 8th, 1969

Investigation into service fault on Hackbridge and Hewittic 120 MVA. 275/33 kV. transformer installed as SGT1 at Kilmarnock Substation

Summary: Detailed investigation into the 8th November service fault on the Hackbridge 120 MVA. 275/33 kV. transformer SGT1 at Kilmarnock Substation has failed to reveal any reason to suggest return of the transformer to the manufacturers works. Accordingly, the damage suffered by the transformer and its ancillaries is to be repaired and the equipment reinstated.

I. INTRODUCTION

At 03.05 hours on Saturday, 8th November, 1969 during a particularly severe storm covering Central South West Scotland, the Hackbridge & Hewittic, 120 MVA. 275/33 kV. star/delta connected supergrid transformer, serial No. 98728 originally commissioned in March 1965, as SGT1 at Kilmarnock Substation, became involved in a major fault. (See Baillieston Group Transmission Section CSM.5 Fault Report).

It would appear that following a lightning strike, an arcing fault developed in the vicinity of, or at, the Kilmarnock supergrid transformer SGT1. It is stated that arcing was sustained for some 30 minutes or so. A fire ensued and extensive arcing damage was caused in the immediate vicinity of the transformer and within the substation.

This report deals with that aspect of the incident which involved the supergrid transformer, SGT1 installed at Kilmarnock.

II. PRELIMINARY FAULT INVESTIGATION

Preliminary site examination of the transformer and its associated equipment revealed that the "A" (red) phase 275 kV. bushing had been burnt away leaving only a 4 ft. length of stump of the oil impregnated paper condenser body projecting from the bushing turret, the anti-fog profile porcelain weather-shield having fragmented permitting the bushing oil filling to fire.

The post insulator supported tubular copper busbar to the "A" (red) phase 275 kV. transformer bushing had detached itself from the bushing termination and had fallen across the Buchholz relay oil feed pipe connection between the conservator and the main transformer tank. Extensive arcing damage and various punctures in the Buchholz relay oil feed pipe and the bushing turret oil equalising pipes had occurred.

Extensive arcing, possibly from this falling busbar, had also occurred to the two cooler mounted pressure relief devices and the cooler mounted oil conservator, the latter having been punctured at the conservator end plate in the vicinity of the top of the oil level gauge.

Resulting from these occurrences, an oil fire ensued. Evidence confirms with reasonable certainty that this fire was confined to the immediate locality of the "A" phase 275 kV. bushing, being, in the first instance, attributed to the 50 gallon oil filling of the 275 kV. oil impregnated paper bushing itself. Later, however, a small quantity of oil was fed to the fire from punctures in the conservator and other oil feed pipes.

The/

The live and earth electrodes of the "A" phase, 48 inch co-ordinating rod gap mounted on the support insulator structure some 20 ft. from the transformer had been melted away due to the extensive arcing evidenced. The phases "B" and "C" co-ordinating gap electrodes and their support structures were undamaged.

It is reported by the Fire Officer and subsequently supported by the Group Transmission Engineer that after the fire had been extinguished, oil was still flowing from holes punctured by arcing in oil feed pipes. Due to these pipes being hot, the leaking oil repeatedly ignited and the resulting fires had to be extinguished by the fire fighting staff. The significance of this evidence is to confirm that oil was still in the transformer conservator after the main fire had been extinguished and hence, the transformer remained at all times during the fire incidence under positive oil pressure. Therefore, the transformer oil filling could have effectively preserved the transformer from fire damage.

It was also noted that only very short stump ends remained of the live and earthed arcing horn electrodes fitted to the "A" phase 275 kV. bushing. The bushing arcing horns, set at 58 inches, were undamaged on the phases "B" and "C" 275 kV. bushings of the faulty transformer SGT1 and all three phases (bushings) on the sister transformer, SGT2.

III. DETAILED SITE INVESTIGATION

A detailed site inspection of the damaged "A" phase 275 kV. transformer bushing fitted to SGT1 revealed that the complete porcelain weathershield had disintegrated thereby exposing the internal oil impregnated paper condenser core which had been badly burned into a 4 ft. long charred stump. At a position approximately 1 ft. down from the bushing "conservator", which carries the external terminations, the bushing central brass tube supporting the bushing conservator had bent into a dropping position; the tube being split and badly damaged by arcing at the bend. The H.V. phases "B" and "C" bushings together with all six (2 in parallel/phase) L.V. bushings appeared to be undamaged.

Considerable arcing between the "A" phase 275 kV. busbar and adjacent steelwork had taken place during the fault and numerous arc roots were found on the conservator, the two pressure relief devices, the radiator headers and top oil pipework. Holes had been burned in the top of the conservator oil gauge chamber, the equalising feed pipes between the conservator and the main tank and bushing turrets, the two pressure relief devices and one of the top pipework expansion bellows. The conservator oil feed pipe to the main transformer tank was also severely discoloured in the region of the contact point with the 275 kV. fallen busbar, possibly indicating that it had been subjected to considerable heating due to fault current.

As a result of the oil fire which ultimately spread locally to ground level and also due to the multiple extraneous earth currents evidenced, all multicore cabling between the transformer/cooler bank and the marshalling kiosk had been irretrievably damaged. The cooling plant bottom pipework, isolating valves, pumps and fans had all been involved in the fire but damage appeared to be superficial. Oil was dripping from one of the oil pump flanges.

The capillary tubes of both winding temperature indicators had also been involved and the maximum temperature pointers were found off scale hard against the scale end stops. It is considered that this is not indicative of the maximum temperature the windings reached during the fault but due to involvement of the capillaries in the fire.

The/

The oil fire had also discoloured but not seriously damaged the paintwork at the cooler bank end of the main transformer tank. The driving mechanism compartment of the on-load tap change equipment had not been affected by the fire and the multicore cables between this and the marshalling kiosk appeared to be in good condition

The glass diaphragms of both pressure relief devices were found to have shattered but here again it was considered that this was due to Fire involvement and sustained arcing between the transformer bushing/busbar and the pressure relief devices during the fault period.

The silica-gel breather was in excellent condition; the colour of the gel being bright blue to indicate a dry state.

An examination of the on-load tap change equipment selector mechanism through the top access cover, revealed no internal distress. The tap changer was found to be on tap position No. 8 after the fault.

To establish the internal condition of the transformer, oil was lowered in the main tank to a point level with the top clamping structure thereby leaving all insulation covered. Limited inspection of the core and windings through the two handhole covers located at the ends of the transformer cover, failed to reveal any internal damage. All internal surfaces were clean and no discolouration of the oil was observed. The main paper covered line entry lead from the H.V. phase "C" bushing to the centre point of the windings and the paper covered tapping connections to the tap changer terminal board of this phase were inspected for discolouration due to heat, movement due to short circuit forces, etc., but all appeared in good condition. No movement or looseness in the winding clamping structure could be observed.

To inspect the condition of the current transformers located in the H.V. phase "A" bushing turret and also to esablish the conditions of the internal pull-through flexible copper connection, the stump end portion of the damaged bushing was removed. This enabled the end quadrant of the H.V. phase "A" top Permali coil clamping ring together with the top 12 disc coils and the "A" phase 275 kV. line lead connection to be examined but no sign of movement or any distress was detected.

The damaged H.V. phase "A" bushing was removed by cutting the central brass tube at a point below the damaged bent section so that the remainder of the bushing could be slipped over the internal flexible lead. Upon removal, examination of the bushing re-entrant oil immersed end showed this to be undamaged and in excellent condition. The central flexible line connection was also in good condition up to a point approximately 2 ft. from the bushing conservator. Over this 2 ft. or so the paper wrapping had been badly burned and the copper flexible was discoloured. Apart from this and a few broken strands in the surface layer at the point where it had been sharply bent within the bushing central tube the bushing flexible was intact.

Inspection of the current transformers located in the bushing turrets revealed no distress and subsequent checks carried out by the Protection Group confirmed that they were in good order.

A quantity of charred paper was found in the inverted cone forming the gas bubble deflector located on the line entry lead immediately below the bottom re-entrant end of the damaged "A" phase bushing. A few globules and particles of brass were also found amongst the charred paper. The globules had obviously dropped down the central brass tube of the bushing from the bent and burnt section of the bushing central tube at the time of the fault/

fault while the brass swarf resulted from having to saw through the tube to facilitate bushing removal. Because of its position, it can be confidently assumed that all debris falling down the central bushing tube had been effectively collected by the gas bubble deflector and that none has entered the transformer.

Because of concern regarding the possibility of water having entered the transformer through the damaged "A" phase 275 kV. bushing, or holes burned in oil pipework, a thorough internal inspection for confirmatory evidence was carried out. No evidence of water was found except a few globules resting on the top horizontal surfaces of the bushing C.T.'s and the "A" phase winding Permali clamping ring. It is almost certain however that this entered the transformer from the bushing flange when the faulty H.V. phase "A" bushing was removed. By lowering a hand lamp into the oil an attempt was made to establish whether any water was lying at the bottom of the tank. Due to obstructions, depth of oil etc., this could not be determined. Because, however, oil still remained in the conservator after the fire was extinguished, a positive oil pressure would exist throughout the fault/fire and therefore it can be said with reasonable certainty that no water, entered the transformer during the fault incident.

IV. SITE TESTS

Site tests comprising 433 volt ratio and magnetisation current check test, Vector group and 1000 Volt megger check was satisfactorily carried out by Hackbridge and Hewittic and S.S.E.B. personnel, the latter test revealing - H.V. - Earth, 60 M.ohms; L.V. - Earth, 60 M.ohms and Core - Earth, 100 M.ohms (Earth link removed).

Oil samples taken from the top and bottom of the main tank when analysed by G.E.C., Manchester, gave the following satisfactory main constituent gases:-

	Main Tank Top	Main Tank Bottom
Hydrogen	14 p.p.m.	18 p.p.m.
Methane	30 p.p.m.	30 p.p.m.
Ethylene	10 p.p.m.	9 p.p.m.
Propane	-	-
Ethane	3 p.p.m.	3 p.p.m.
Carbon Dioxide	150 p.p.m.	150 p.p.m.
Carbon Monoxide	1.9 p.p.m.	1.9 p.p.m.
Acetylene	6 p.p.m.	6 p.p.m.
Water content of oil	16 p.p.m.	18 p.p.m.

Insulation and winding resistance tests carried out on the motors of the cooler pumps and fans show these to be satisfactory but a three-phase supply check test of these will be carried out as soon as possible.

V. FAULT CURRENT AND VOLTAGE ASSESSMENT

Resulting from detailed calculations by the Transmission Design Engineer, (Memo. ref. EDO.16.4/RBH dated 18th November refers) a check has been made in collaboration with Hackbridge design staff to determine whether the initial and subsequent steady - state fault currents arising during the incident would have had any deleterious effect on the transformer.

Design/

Design studies reveal however that the magnitude and duration of the fault currents detailed by the Transmission Design Engineer arising is well within the capability of the transformer and the transformer windings should not therefore have suffered damage.

VI. REMEDIAL MEASURES

Following detailed consideration of all evidence revealed by the site examination and internal inspection, site tests etc., and the subsequent design studies, there was little evidence to support return of the transformer to the manufacturers' works. It was therefore decided to recommend re-instatement of the faulty transformers and in consequence, the following apportionment of work required to return the transformer to a serviceable condition has been tentatively agreed between Hackbridge and Hewittic and S.S.E.B.

Bushing

Hackbridge will supply and fit a replacement length of "A" phase internal flexible lead to fit the "A" phase 275 kV. replacement bushing supplied from Parkhead S.S.E.B. stores.

Fittings

Hackbridge will provide a replacement bellows for the top oil pipework, provide and fit replacement winding temperature indicators and diaphragms for the two pressure relief devices.

Steelwork

The repair of all damaged pipework and steelwork will be carried out by S.S.E.B. including replacement as necessary of burnt gaskets. In this connection, the conservator feed pipe and the oil pipework between the transformer and coolers will be removed for internal cleaning.

Buchholz

This will be removed and checked by S.S.E.B. and if found defective will be replaced.

Cabling

The replacement of all damaged multicore cables will be carried out by S.S.E.B.

Oil

Because the results of oil analysis indicate the oil in the main tank is in good condition it is considered that no useful purpose would be served by replacement. The oil in the coolers and pipework, however, is to be removed and the coolers flushed out with clean oil before refilling. The total oil filling is then to be subjected to high vacuum oil treatment; this work being undertaken in collaboration with Hackbridge after all site remedial works have been accomplished.

Paintwork

Restoration of paintwork will be carried out by S.S.E.B.

Time Scale/

Time Scale

It is estimated that all necessary remedial work can be completed by end November and when the 275 kV. overhead lines have been restored in early December, it is intended, as a precautionary measure to excite the transformer from the Clyde's Mill gas turbines, before returning the transformer to commercial operation.

VII. CONCLUSIONS

The cause of the "A" phase bushing fire can be attributed to either, arcing following mechanical damage caused by the falling 275 kV. busbar or sustained arcing of the bushing arcing horns, or a combination of both. Undoubtedly the positive oil pressure maintained throughout the material time of the incident, effectively preserved the transformer and damage has therefore been limited to peripheral components.

Accordingly, re-instatement of the existing transformer was carried out and it was recommissioned on December 15th, 1969.

Date of Initial Report - November 25th, 1969.

APPENDIX II

275 kV. System Fault - November 8th, 1969

Details of Load Shed or Disconnected in S.S.E.B. Area

1. Load disconnected at Ayr and Kilmarnock on occurrence of fault

District	Grid Supply Point	Consumers Lost	Load	Outage Time	Reason
Kilmarnock	Kilmarnock 275/33 kV.	4,000	10 MW.	03.06 to 03.40	Grid Fault, restored from Barony 33 kV.
		20,000	20 MW.	restored 05.30	
		4,000	4 MW.	restored 09.00	
Ayr	Ayr 275/33 kV.	30,000	30 MW.	03.06 - 05.50	Grid Fault, restored from Coylton
	Total	54,000	64 MW.		Grid Fault

2. Load Shedding

Load disconnected during fault and restoration of system to normal following clearance of fault (other than consumers fed from Kilmarnock/Ayr feeder).

2.1 Central Area

District	Grid Supply Point	Consumers Lost	Load	Outage Time	Reason
Stirling	Devonside & Stirling	28,000	22 MW.	03.27 - 03.35 03.44 - 04.23	Controlled load shed by Bonnybridge Dist. Control Engineer
Falkirk	Cumbernauld Bonnybridge	30,000	29 MW.	03.29 - 03.34 03.44 - 04.20	Controlled load shed by Bonnybridge Control Engineer
Coatbridge	Clyde's Mill P.S.	5,730		03.35 - 05.16	Controlled load shed by C.M. generation staff
Motherwell/ Lanark	"	8,200	47 MW.	03.35 - 05.16	"
Hamilton	"	5,000		03.35 - 05.16	"
Kilmarnock	Kilmarnock				
	Saltcoats			-	Disconnected by fault
Total		76,930	98 MW.	-	-

2.2/

2.2 Edinburgh, Fife and Borders Area

District	Grid Supply Point	Consumers Lost	Load	Outage Time	Reason
Lothians	Cockenzie 33 kV.	12,000	10 MW.	03.20 - 03.45	Controlled load shed by generation staff
Edinburgh	Portobello 33 kV.	26,000	14 MW.	03.30 - 04.45	"
"	Portobello 11 kV.	34,000	22 MW.	03.30 - 04.33	"
"	Dewar Place 33 kV.	20,000	20 MW.	03.42 - 04.00	"
"	Sighthill 33 kV.	26,000	15 MW.	03.40 - 04.40	"
Fife	Cupar 33 kV.	24,600		03.41 - 05.15	Controlled load shed by dist. staff
	Burntisland	4,000		" "	
	Redhouse/ Glenrothes	5,725		" "	
	Leven/Colinsburgh /Anstruther	9,950	42 MW.	" "	
	Levenbank 1 and 2	500		" "	
	Inverkeithing /Rosyth/ Aberdour /part Dunfermline	13,586		" "	
	Balgowie/ Gartarry	1,794			Controlled load shed by Gen. staff at Methil & Bonnybridge
Total		178,155	123 MW.	-	-

2.3 Glasgow/Clyde Area /

2.3 Glasgow/Clyde Area

District	Grid Supply Point	Consumers Lost	Load	Outage Time	Reason
Glasgow North	Dalmarnock 20 kV.	36,000	23 MW.	03.12 - 03.48	Controlled load shed by Gen. staff
	Kilbowie 132/11/33 kV.	18,300	9	03.25 - 05.11	Controlled load shed by dist. staff
	Drumchapel	28,000	14	03.25 - 05.15	"
	Partick	25,000	12	03.26 - 05.06	"
	Part West George St. 275/33 kV.	23,000	18	03.29 - 04.30	"
Glasgow South	Clyde's Mill	3,000	3 2	03.25 - 05.16 03.25 - 05.16	Controlled load shed by Gen. staff
Total		133,300	81 MW.	-	-

3. Summary

		MW.
Load disconnected by fault		64
Load shed -		
Central Area	98	
Edinburgh, Fife & Borders Area	123	
Glasgow/Clyde Area	81	302
Total Lost		366 MW.

APPENDIX III

275 kV. System Fault - November 8th, 1969

Report by System Operations Engineer on the events on 8th November, 1969

1. General

Throughout this report the best endeavour has been made, from all known evidence and logs, to record the most probable timing of events.

The operational staff at Kirkintilloch and Clyde's Mill have indicated that although they wrote up their logs as soon as practicable after the fault their timings of occurrences are suspect to a few minutes either way. In the case of Manchester Grid Control only one event is involved and this concerns the opening of the Strathaven-Harker No. 1 circuit originally timed at 03.38 hrs. but now agreed to be 03.34 hrs. A switching sequence was reported to Manchester at 03.38 hrs. as completed but evidence from a transfer recording points to the line becoming "dead" at an earlier time, i.e. when the two mesh circuit breakers at Harker were opened, the commencement of the switching sequence. Also Kirkintilloch's and Clyde's Mill's logs record events in a chronological order as these times are based on information obtained later.

At Clyde's Mill and Kirkintilloch delays resulted from attention to incoming telephone calls, alarms and indications which could not be ignored completely to allow uninterrupted concentration on the fault because of the possibility of an important message or information being lost.

The overnight staffing at Kirkintilloch consists of:-

1 Senior Control Engineer (2nd Asst. - N.J.B. Grade 4)
2 Assistant Control Engineers (3rd Asst. - N.J.B. Grade 7)

At Clyde's Mill Control Room:-

1 Station Control Engineer, N.J.B. Grade 10
1 Switchboard Attendant, N.J.I.C.

List of Appendices

Appendix	1	System Frequency
"	2	C.E.G.B. transfer MW.
"	3	" " MVAr.
"	4	H.E.B. transfer MW.
"	5	S.S.E.B. total generation output
"	6	" demand (sum of T.G.O. and transfer)
"	7	System voltage 275 kV. (Windyhill and Kincardine)
"	8*	" " 132 kV. (Galashiels and Dumfries)
"	9*	" " 11 kV. (Chapelcross and Yoker)
"	10*	Times of shutdown and start up of power stations - see Appendix IV
"	11	Chart showing estimated reduction in demand
"	12	Diagram of system around Strathaven
"	13*	System diagram of connections - see Fig. 1 of main report
"	14	Thunderstorm recorder
"	15	S.S.E.B.- C.E.G.B. transfer Strathaven Harker No. 1 (from Manchester)
"	16*/	

Appendix 16* Extract from daily load curve.

* not reproduced for this report.

Weather Conditions

The last forecast received at 20.30 hrs. on Friday 7th was "South West gales becoming severe later today and tonight. Likely to increase to storm force with gusts of 75 m.p.h. Risk of thunderstorms in this area during the next 24 hrs. Lightning risk one."

The high winds did not materialise but the thunderstorm recorder at Grid Control recorded some electrical discharges prior to the fault and either more severe or closer disturbances about the time of the fault.

Calder Hall also recorded electrical discharges on their lightning sensor. (Copy of Calder Hall report received from Manchester Grid Control).

System Conditions and Control

The system was connected normally and the only significant transmission lines not in service were the Clyde crossing (275 kV.) and the Strathaven-Harker No. 2 circuit which was under Permit to Work. Extra hydro generating plant was running in the H.E.B. and in South Scotland (Galloway) because of excess water resulting from heavy rain on previous day. All other plant and loadings were normal.

Clyde's Mill 33 kV. Control Room has supervisory control of Busby, Giffnock, Strathaven, Wishaw, Ravenscraig, Easterhouse, Queenslie, Coatbridge, East Kilbride, Motherwell, Hallside Grid Substations, and direct wire control of the 132 and 275 kV. Substations at Clyde's Mill, the 33 kV. distribution feeders and Clyde's Mill generation.

2. System Conditions just prior to the Fault

Transfers	from C.E.G.B.	import 28 MW. (programmed "float")
	from H.E.B.	import 386 MW. (on programme)
	from C.E.G.B.	import 50 MVAr (approx. half of MVAr. gain of interconnectors).

Frequency 50.03 Hz.

System Voltages 138 kV. and 275 kV.

Shunt Reactors Switched in at:- Giffnock, Wishaw, Dewar Place, Shrubhill, Sighthill (all on tap 1, 30 MVAr absorption).

West George St. (tap 5, 45 MVAr absorption)

Neilston (not tapable, 50 MVAr absorption)

a total of 6 x 30 + 2 x 45 + 50 = 320 MVAr absorption.

Windyhill's reactor was switched out at 02.45 hrs. to lift Windyhill's volts with Cruachan pumping.

Generation (All Scotland)/

Generation (All Scotland)

S.S.E.B.	Barony	(2 sets)	45	H.E.B.	
	Cockenzie	(2 sets)	488	Carolina Port 'B' (2 sets)	104
	Methil	(2 sets)	60		
	Hunterston	(6 sets)	334	Hydro (not known)	579
	Chalepcross	(8 sets)	176		683 MW.
	Galloway	(4 sets)	36		
	Lanark	(4 sets)	14		
	Kincardine	(0 sets)	- 7		
			1,146 MW.		
All Scotland			1,829 MW.		

Demand (All Scotland)

S.S.E.B.	1,325 MW.
H.E.B.	297 MW.
Cruachan Pumping (2 sets)	220 MW.
	1,842 MW.

3. System Condition after the Fault

03.06 Severe surge on system.
Switches SG1 SWA, SG1 SWB, SG2 SWA, SG2 SWB at Kilmarnock and switches SG1 and SG2 at Ayr (indicated tripped at G.C.C.).

03.07 Loss of 49 MW. of demand. (Later re-estimated as 64 MW.).
Protection staff state that switch H85, the Kilmarnock No. 2 line circuit breaker at Strathaven opened 6 cycles after the fault.
Switch H115 did not open to clear the No. 1 line. No indication received at G.C.C. from Strathaven of any circuit breaker change. 132 kV. system voltage fell to between 100 and 120 kV. Recovered immediately to 135 kV. 275 kV. system voltage fell to between 200 and 215 kV. Recovered immediately to 265/270 kV.
C.E.G.B. MVAr transfer off scale (import to S.S.E.B. greater than 500 MVAr).

03.08 Voltage commenced falling at 2 kV./min. G.C.C. standby diesel took over essential G.C.C. supplies automatically. Grid Control supplies were isolated from system disturbances and these could not be seen by the Grid Control staff.

03.09 Ayrshire Distribution Control requested immediate opening of switch H115 at Strathaven as transformer SGT1 was on fire in Kilmarnock 275 kV. Substation. (Bushing co-ordinating gap flashed over, sustained power arc damaged bushing and set oil on fire). Cockenzie 2 sets (488 MW.) Hunterston 6 sets (334 MW.) tripped by protection; Cruachan switched out 2 pumps (220 MW. demand).

03.10 Clyde's Mill Control instructed to open switch H115 at Strathaven; system frequency now falling at 0.04 Hz/minute. Standby transmission staff and System Operation day staff were called out. Methil 1 set (30 MW.) tripped by Protection. H.E.B. hydro plant tripped (18 MW.)
System/

03.10 System voltages starting to fall from their recovered position. C.E.G.B. MW. transfer oscillating and rising to 150 MW. import. Ayrshire Area requested switch H85 to be opened at Strathaven.

03.11 Clyde's Mill Control reported unable to open switch H115 at Strathaven and were instructed to try again and also to open switch H85 at Strathaven.
At this time the first and only indication of circuit breaker operation at Strathaven was received at Clyde's Mill Control and Grid Control; switch H85 indicated open. (This was a delayed indication which managed to get through as Clyde's Mill did not have time to select and open on supervisory).
The "Strathaven Supervisory Engaged" signal at Clyde's Mill Control indicating and cancelling from time to time. Clyde's Mill Control Room in darkness. Normal lighting had become non-existent and emergency lighting did not come on.

03.12 Dalmarnock opened Grid L.V. switches and local feeders, shedding 23 MW. of load as station staff believed Grid supplies had failed. H.E.B. lost another 29 MW. of generation on hydro stations.
System voltages now 254 kV. and 133 kV.
Neilston Control instructed to switch out Neilston 50 MVAr. shunt reactor.

03.14 Change in C.E.G.B. MVAr import - momentarily came to float.
C.E.G.B. MW. export to S.S.E.B. rising.
Clyde's Mill Control reported unable to open switch H115 at Strathaven, instructed by Grid Control to keep trying.
Lanark hydro 14 MW. tripped by hand.

03.15 Second major downward swing in system voltages; levels falling below 100 kV. on 132 system and below 200 kV. on 275 system.
Methil 1 set (30 MW.) partially unloaded and tripped by hand.
Barony 2 sets (45 MW.) tripped by hand.
Carolina Port 'B' 2 sets 104 MW. tripped in negative phase sequence protection.
H.E.B. lost 43 MW. of hydro generation.

03.16 System frequency 49.8 Hz and falling.
MVAr transfer with the C.E.G.B. 500 MVAr to S.S.E.B.
MW. transfer with the C.E.G.B. oscillating touching 400 MW. to S.S.E.B. Clyde's Mill Control still attempting to open switch H115 at Strathaven on supervisory. Trying to catch the selection of switch H115 in between clearance of "Strathaven Supervisory Engaged" alarm on facia. Reporting periodically to Kirkintilloch that attempts to open were unsuccessful. Instructed to keep trying.

03.17 Loss of 54 MW. of generation on hydro plant in H.E.B.
Recorder of MW. transfer with C.E.G.B. oscillating from 400 MW. Import to 100 MW. export.

03.18 Clyde's Mill Control instructed to discontinue attempts to open switch H115 at Strathaven and to open switches L50, L60 and W10 at Strathaven to clear circuits off the Strathaven reserve bar.
C.E.G.B. North East Region lost first unit at Blyth (124 MW.)
11 kV. busbars at Chapelcross now down to 8.5 kV.

03.19/

03.19 Clyde's Mill Control reporting no success in opening switches L50, L60 and W10 at Strathaven. Instructed by Grid Control to keep trying.

03.20 Chapelcross (U.K.A.E.A.) 8 sets tripped (176 MW.) (2 sets tripped by hand, 6 automatically).
H.E.B. lost 100 MW. of generation.
C.E.G.B. North East Region lost 114 MW. at Blyth.
Galloway Hydro lost 13 MW.
Cockenzie shed local 33 kV. supplies (10 MW.) and the station auxiliary supply.
Voltage recorders off scale on 275 and 132 kV. systems. (On 132 kV. voltage recorders lower limit is 100 kV. and upper limit 160 kV. On 275 kV. recorders corresponding values are 200 kV. and 320 kV.)
System frequency 49.67 Hz.
Request by Glenlee to come out of parallel and maintain local supplies. Instructed to stay on the Grid and run up all machines.
Dunfermline instructed to put the gas turbines on load.
Kincardine and Methil instructed to come on load.
Tongland instructed to come on load.

03.22 Kilmarnock Power Station opened the 22 kV. interbus transformers.

03.23 System frequency at minimum of first downward swing, 49.66 Hz.

03.25 Blyth G2 tripped by hand (112 MW.)
Stirling Area Control shed 51 MW. of supplies because of low system voltage and a low reading on the frequency meter.

03.26 Blyth (C.E.G.B. N.E.R.) G6 tripped by hand (180 MW.)
Clyde's Mill Control reported no success at opening the circuit breakers at Strathaven. Instructed to keep trying.

03.28 System frequency rising.
Windyhill shed 35 MW. Frequency meter at Windyhill reading low as a result of low voltage.

03.29 Clyde's Mill Control instructed to open switches W10, W16 and F40 at Busby. (Busby line switches to reserve busbar at Strathaven). Glasgow Area shedding load. (18 MW. shed).
Frequency still rising, now at 49.84 Hz.
Leeds Grid Control commenced load shedding because of line loadings.

03.30 Clyde's Mill Control reported switches W10, W16 and F40 opened at Busby. Instructed to open switch SG2 at Hallside, switches H20 and W30 at Clyde's Mill 275 kV. and switches 285 and 685 at Clyde's Mill 132 kV. Substation (Clyde's Mill switches to reserve bar at Strathaven). National Control asked to open the Strathaven-Harker No. 1 circuit at Harker. (Connected to reserve bar at Strathaven.
Glenlee put 2 machines on load.
All Power Stations, not previously told, now instructed to come on load as soon as possible with all plant.

03.31/

03.31 Clyde's Mill reported switch SG2 at Hallside, switches H20, W30, 285 and 685 opened.
Instructed to open switches 180, W20, F65 at Wishaw. (Wishaw connecting to Strathaven reserve bar).

03.32 Mr. Petrie of Baillieston Transmission staff arrived at Strathaven and heard two circuit breakers opening. Switches W10 and L60 (bus coupler switch at Strathaven and Wishaw line switch to reserve busbar at Strathaven). This cleared the S.S.E.B. infeeds to the reserve bar at Strathaven.
The fault was now being fed from Harker.
Manchester Grid Control instructed Carlisle to open the Strathaven No. 1 circuit breakers at Harker, the line isolator, and to reclose the Harker mesh (two circuit breakers).
Clyde's Mill Control reported unable to open the circuit breakers at Wishaw. Instructed to try again.

03.33 Portobello Power Station shed all local load (36 MW.). Busbar voltmeter reading zero.

03.34 Clyde's Mill Control reported switches 180, L40 and W20 at Wishaw opened.
Mr. Petrie reported switches W10 and L60 opened at Strathaven, he was instructed to trip switch H115 at Strathaven. Frequency falling.
Harker-Strathaven No. 1 circuit opened at Harker. This disconnected the fault from the system.
System frequency commenced to fall rapidly.
The C.E.G.B. MW. transfer increased to over 1000 MW. to S.S.E.B. and the megavar transfer with the C.E.G.B. was swinging between 400 MVAr import and export 200 MVAr.
Voltage recorders show a rapidly rising system voltage.

03.35 Stirling Area restored load with restoration of voltage.
Distribution Controls instructed to shed 50% of demand.
National Control teleprinted requesting the Harker-Strathaven No. 1 circuit to be closed as severe overloading was occurring in north east England. Leeds had shed about 115 MW. of demand by this time. Tongland generation coming up to full load.
Stonebyres generation on load.
System day staff arriving at Grid Control.

03.36 Cruachan Control instructed to come on load with all machines as soon as possible. Cruachan having difficulty with relays and no auxiliary supply. Cruachan told supplies available from Windyhill to Dalmally and to get all generation on as soon as possible.
H.E.B. Control told to get all plant on the bars and to be prepared to export up to overload conditions on tie lines to S.S.E.B. H.E.B. experiencing difficulty with very high voltage (160 kV.). H.E.B. Control told, regardless of voltage, to put all generating plant on the bars and pick up as fast as possible.
Dunfermline experiencing difficulty synchronising gas turbines because of high system voltage. System voltages now rising steeply. Auxiliary supplies restored at Cockenzie.
Clyde's Mill Control shed local load (47 MW.) on instruction.

03.37/

03.37 MVAr export to the C.E.G.B. rising.
MW. import from C.E.G.B. off scale (greater than 1000 MW.)
MW. transfer with H.E.B. "float".

03.39 Mr. Petrie reported that he had manually tripped switch H115 at Strathaven.

03.40 C.E.G.B. MW. transfer recorder back on scale, 980 MW. import to S.S.E.B.
Leeds Grid Control still shedding load.
S.S.E.B. shedding of load continuing.

03.44 Strathaven-Harker No. 1 line energised from Harker.
S.S.E.B. lead shedding by disconnection completed (366 MW. of demand shed).
Leeds load shedding virtually completed (176 MW.)
H.E.B. increasing generation.
C.E.G.B. MW. transfer down to 850 MW. import to S.S.E.B.
C.E.G.B. MVAr transfer exceeding 400 MVAr export from S.S.E.B.

03.45 Bonnington generation on load.
System 275 kV. voltage reaching its maximum of 320 kV.
System 132 kV. voltage reaching its maximum (in excess of 150 kV. in places).
C.E.G.B. MVAr transfer reaching its maximum of 455 MVAr export from S.S.E.B.
H.E.B. exporting 50 MW. to S.S.E.B. and increasing.

03.48 Windyhill Control instructed to close shunt reactor.

03.52 Neilston Control instructed to close the shunt reactor (50 MVAr).

03.54 Clyde's Mill Control unable to close switch W10 (bus coupler) at Strathaven as instructed by Grid Control.

03.55 First thermal plant reconnected at Portobello H.P. C.E.G.B. MW. transfer reduced to 750 MW. import to S.S.E.B. System frequency now 50.05 Hz.

04.00 Switches F44 and F40 at Busby closed successfully by Clyde's Mill Control on instruction.
(Strathaven-Harker No. 1 circuit back on load).
System frequency now 50.1 Hz.
System voltage reducing (300 kV.).
C.E.G.B. transfer now 680 MW. import to S.S.E.B.
H.E.B. generation picking up 120 MW. export to S.S.E.B.

04.04 Clyde's Mill Control unable to close switches L40 and W20 at Wishaw, as instructed. (Override control not used).

04.05 First gas turbine on load at Dunfermline.
System voltage returning to normal (285 kV.)
System frequency normal (50.05 Hz).
C.E.G.B. transfer 650 MW. import to S.S.E.B.
C.E.G.B. transfer 150 MVAr export from S.S.E.B.

04.07 Clyde's Mill Control instructed to close switches H26, H20 at Clyde's Mill 275 kV. S.S. W36, W30 at Clyde's Mill 275 kV. S.S. 285, 685 at Clyde's Mill 275 kV. S.S.

04.10/

04.10 Clyde's Mill Control reported switching completed.

04.13 Kilmarnock Area restored supplies (10 MW.).

04.15 Clyde's Mill brought 2 HP machines on load.
Stage 2 at Galloway hydro coming on load.
C.E.G.B. transfer now 580 MW. import to S.S.E.B.

04.15 Cruachan No. 4 on load.

04.19 Clyde's Mill Control instructed to close switches L40 and W20 at Wishaw. Completed.

04.20 Clyde's Mill Control instructed to close switches L60 at Strathaven. Completed.

04.22 Clyde's Mill Control instructed to close switches 180 at Wishaw. Completed.

04.25 Clyde's Mill Control instructed to close switches W16 and W10 at Busby. Completed.
System frequency 49.93 Hz.
C.E.G.B. transfer now 550 MW. import to S.S.E.B.
C.E.G.B. MVAr transfer 90 MVAr export from S.S.E.B.
System 275 kV. voltage now 282 kV.

04.35 Clyde's Mill Control instructed to close switch W10 at Strathaven. (Transmission system now back to pre-fault conditions except for faulty circuit).

04.45 System frequency and voltage now normal.
Agreed with National Control to come to a programme of import 200 MW. to S.S.E.B. as generation built up before restoring load shed. Distribution controls instructed to commence limited load restoration. Restoration of load in Leeds Area now almost complete.

05.00 Arranged programme of import 200 MW. achieved. MVAr transfer, system voltage and frequency all normal.
Cruachan Unit No. 2 on load. Generation building up at Barony, Bonnybridge, Clyde's Mill, Dunfermline, Galloway Hydros, Portobello Generating Stations.
S.S.E.B. import from H.E.B. hydros 475 MW.

05.15 Load restoration proceeding (completed 05.50 hours.)
First estimates of generating plant expected to be available for the morning peak showed a substantial deficit. The C.E.G.B. stated the maximum transfer to Scotland that system stability could allow would be 900 MW. A pessimistic estimate put the deficit at 1300 MW. and as a precaution a warning of four stages of load reduction was issued. This warning was subsequently modified to a warning of two stages of load reduction, as more generating plant became available. No voltage reduction was necessary and the breakfast peak was met with a deficit of 345 MW. which was imported from the C.E.G.B.

4. Private Generation Affected by the Fault

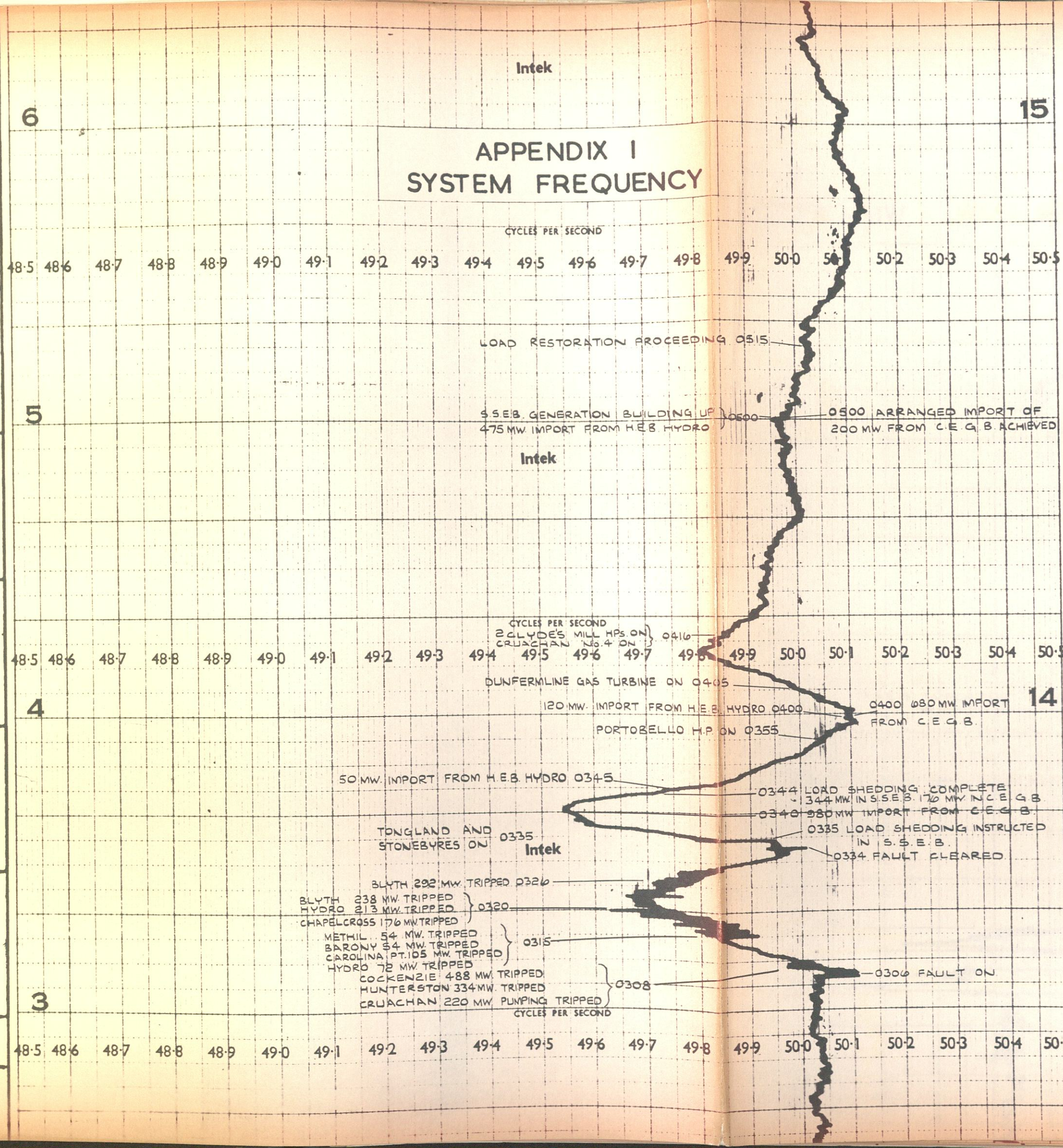
Ravenscraig (Colvilles) lost 275 kV. supply at 03.06 hrs. and generators 4 and 5 tripped. Generators 1, 2 and 3 shutdown at 03.30 hrs. Re-synchronised 07.30 hrs.

British Petroleum (Grangemouth) lost 5 generators through low voltage.

Bowhill (N.C.B.) tripped on overcurrent.

Nairns (Kirkcaldy) lost 2 machines on directional earth fault.

APPENDIX I
SYSTEM FREQUENCY


CYCLES PER SECOND
48·5 48·6 48·7 48·8 48·9 49·0 49·1 49·2 49·3 49·4 49·5 49·6 49·7 49·8 49·9 50·0 50·1 50·2 50·3 50·4 50·5
6
5
4
3
15
14
LOAD RESTORATION PROCEEDING 0515
S.S.E.B. GENERATION BUILDING UP 475 MW IMPORT FROM H.E.B HYDRO 0500
0500 ARRANGED IMPORT OF 200 MW FROM C.E.G.B ACHIEVED
Intek
CYCLES PER SECOND
2 CLYDE'S MILL HPs ON CRUACHAN No.4 ON 0416
DUNFERMLINE GAS TURBINE ON 0405
120 MW IMPORT FROM H.E.B. HYDRO 0400
0400 680 MW IMPORT FROM C.E.G.B.
PORTOBELLO H.P. ON 0355
50 MW IMPORT FROM H.E.B. HYDRO 0345
0344 LOAD SHEDDING COMPLETE 344 MW IN S.S.E.B. 176 MW IN C.E.G.B.
0340 980 MW IMPORT FROM C.E.G.B.
0335 LOAD SHEDDING INSTRUCTED IN S.S.E.B.
TONGLAND AND STONEBYRES ON 0335
Intek
0334 FAULT CLEARED
BLYTH 292 MW TRIPPED 0326
BLYTH 238 MW TRIPPED
HYDRO 213 MW TRIPPED
CHAPELCROSS 176 MW TRIPPED 0320
METHIL 54 MW TRIPPED
BARONY 54 MW TRIPPED
CAROLINA PT. 105 MW TRIPPED
HYDRO 72 MW TRIPPED 0315
COCKENZIE 488 MW TRIPPED
HUNTERSTON 334 MW TRIPPED
CRUACHAN 220 MW PUMPING TRIPPED 0308
0306 FAULT ON
CYCLES PER SECOND

RHB/305/1024 377231-054C

FIG. 7
SK.4083

APPENDIX 2

C.E.G.B. TRANSFER – MW.

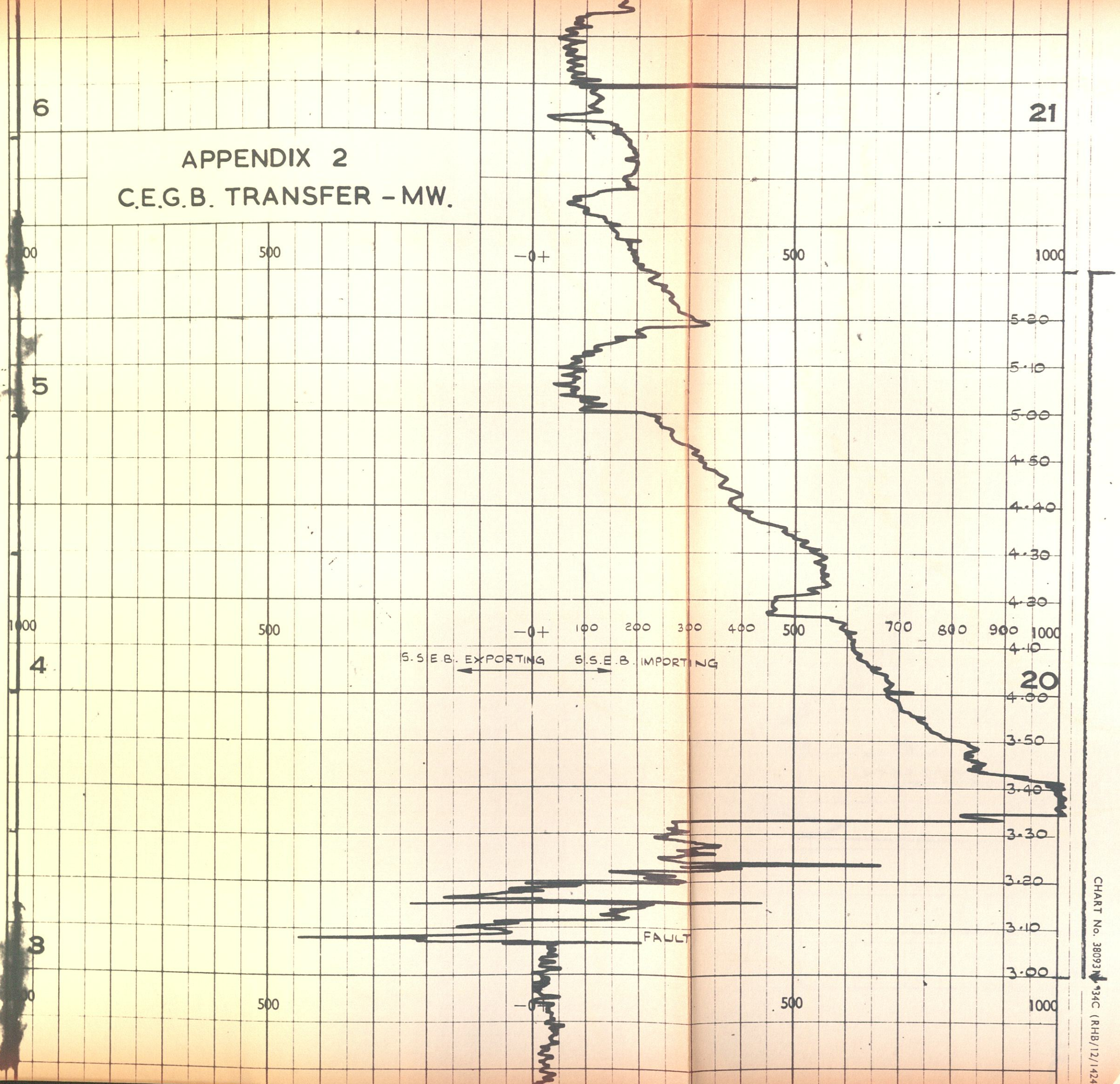


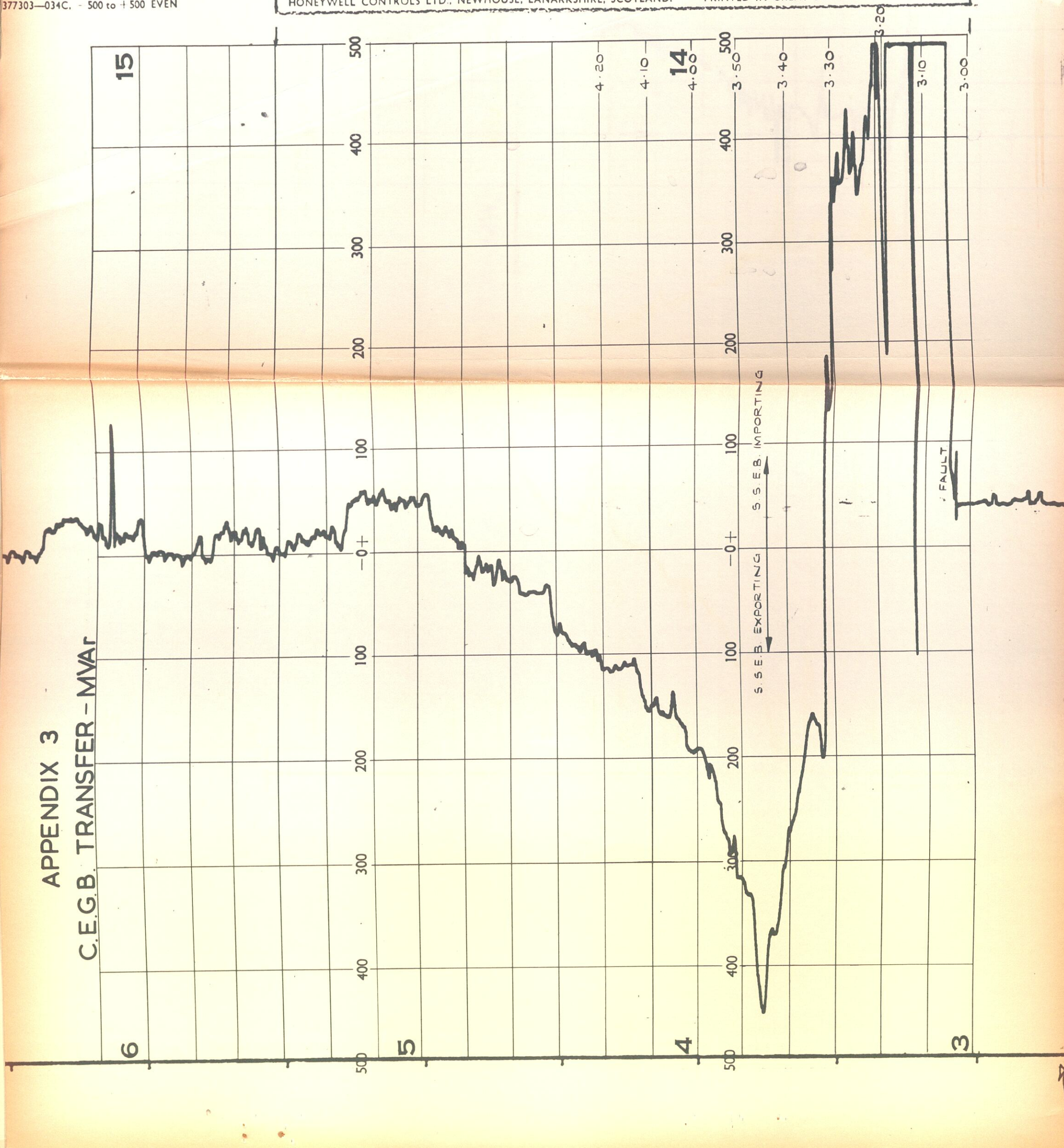
CHART No. 38093N 134C (RHB/12/1424)

377303—034C. - 500 to + 500 EVEN

HONEYWELL CONTROLS LTD., NEWHOUSE, LANARKSHIRE, SCOTLAND. PRINTED IN GREAT BRITAIN

APPENDIX 3

C.E.G.B. TRANSFER - MVAr



APPENDIX 4

N.S.H.E.B. TRANSFER – MW.

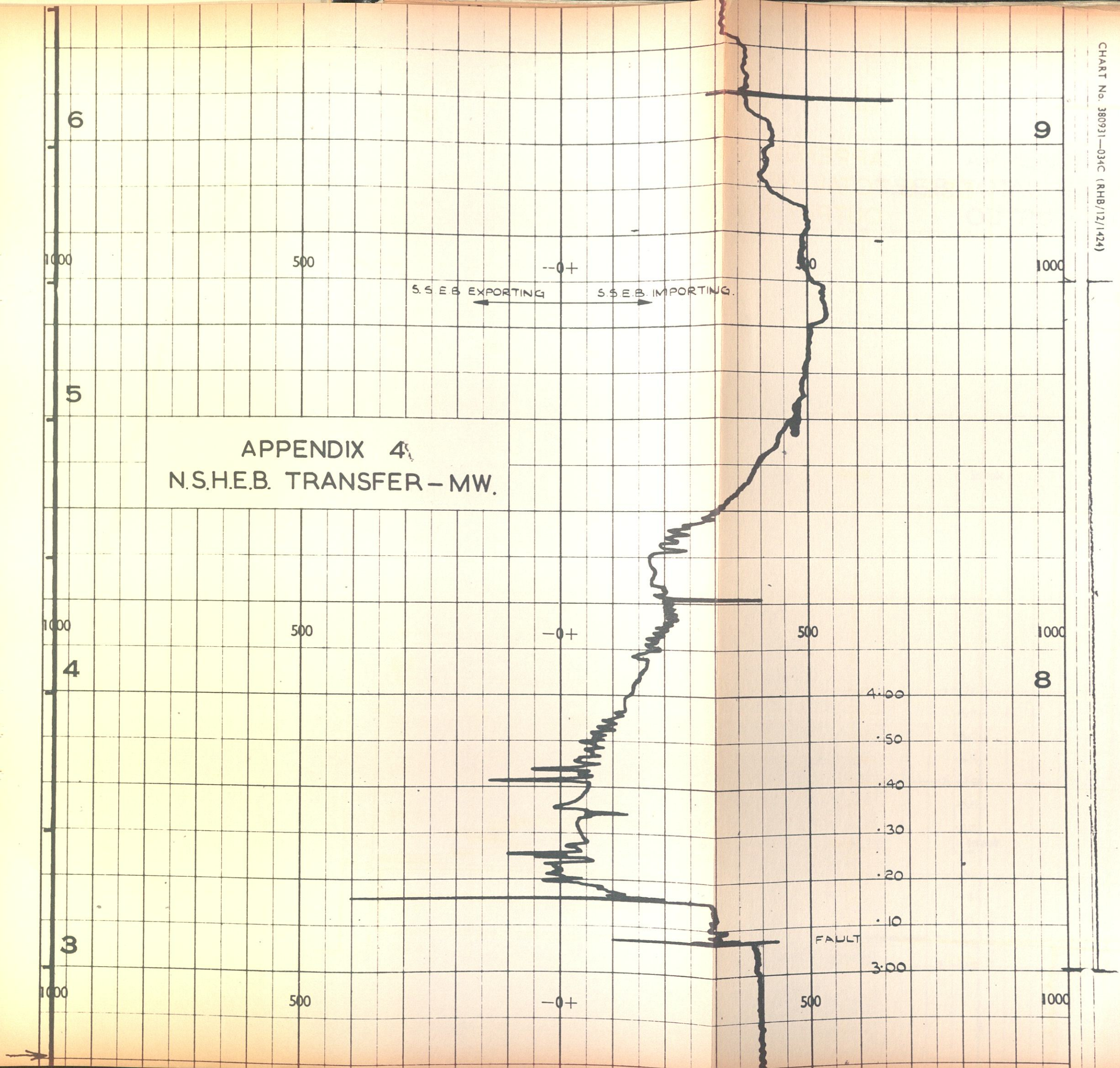


CHART No. 380931—034C (RHB/12/1424)

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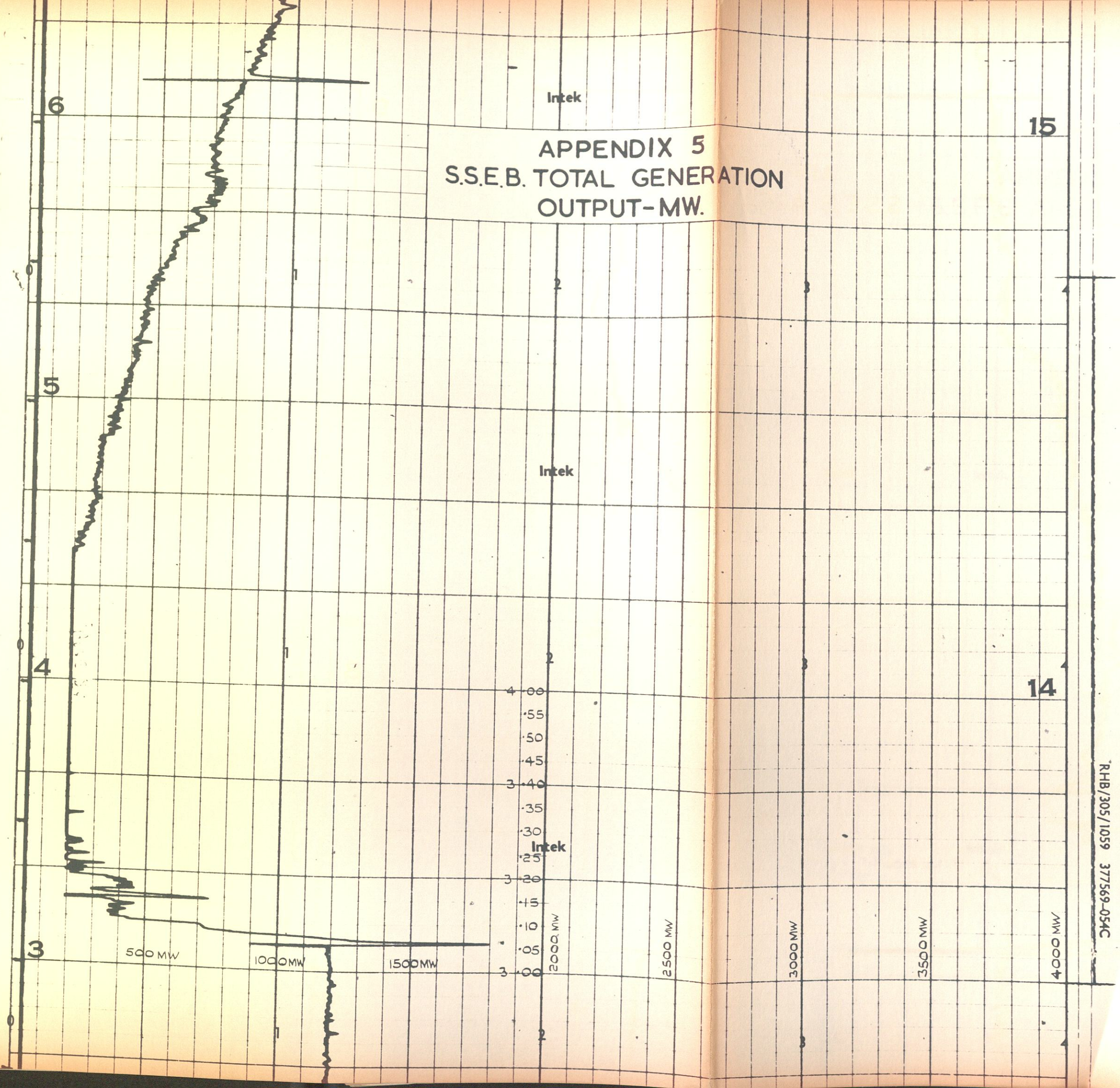
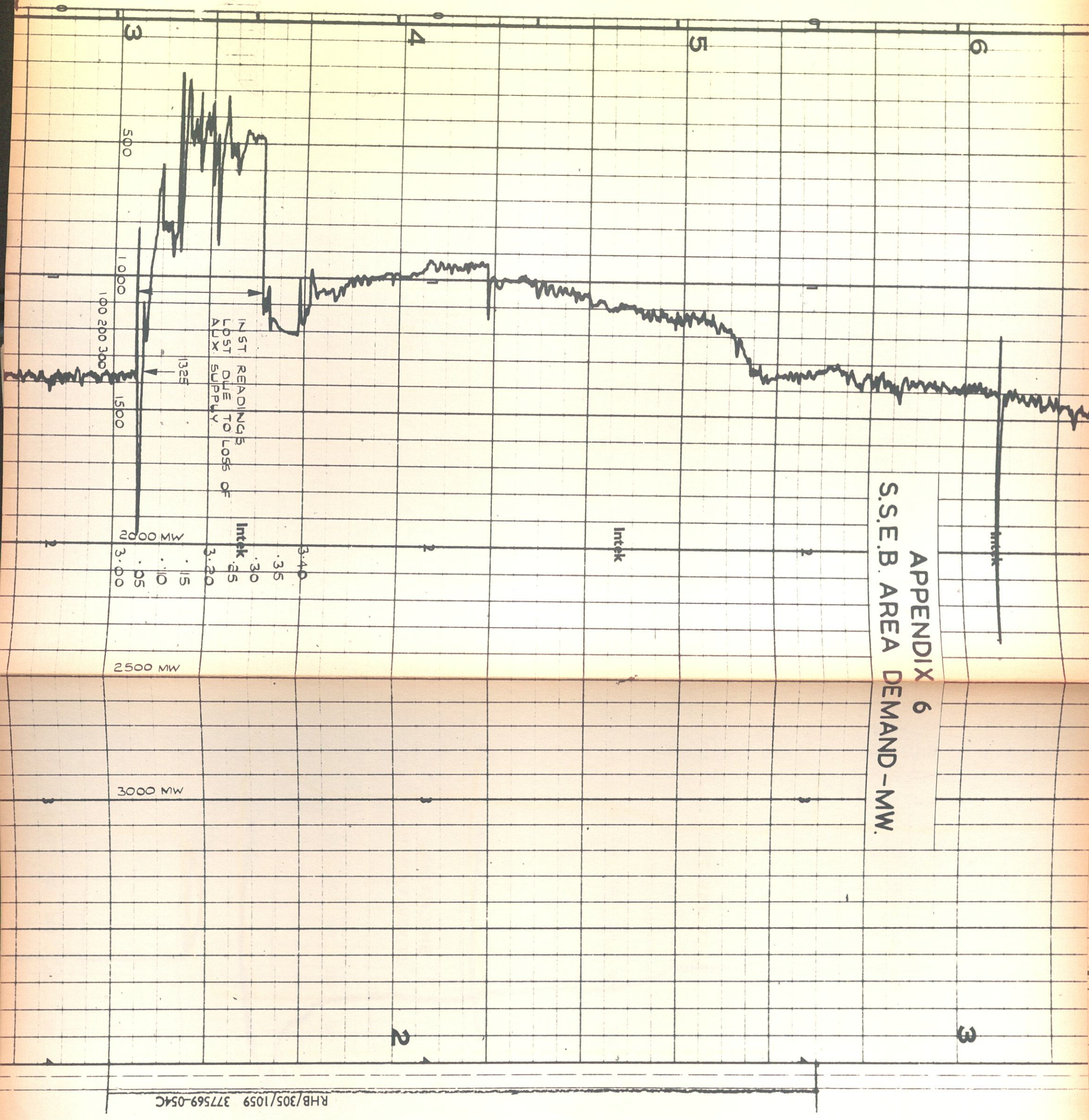
APPENDIX 5
S.S.E.B. TOTAL GENERATION OUTPUT - MW.

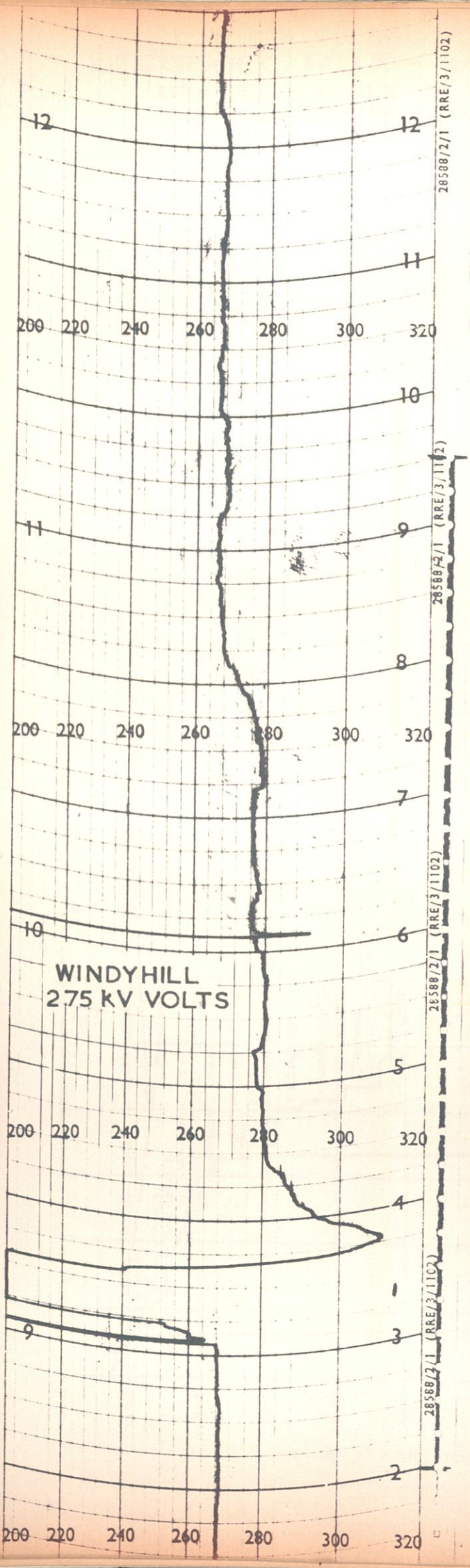


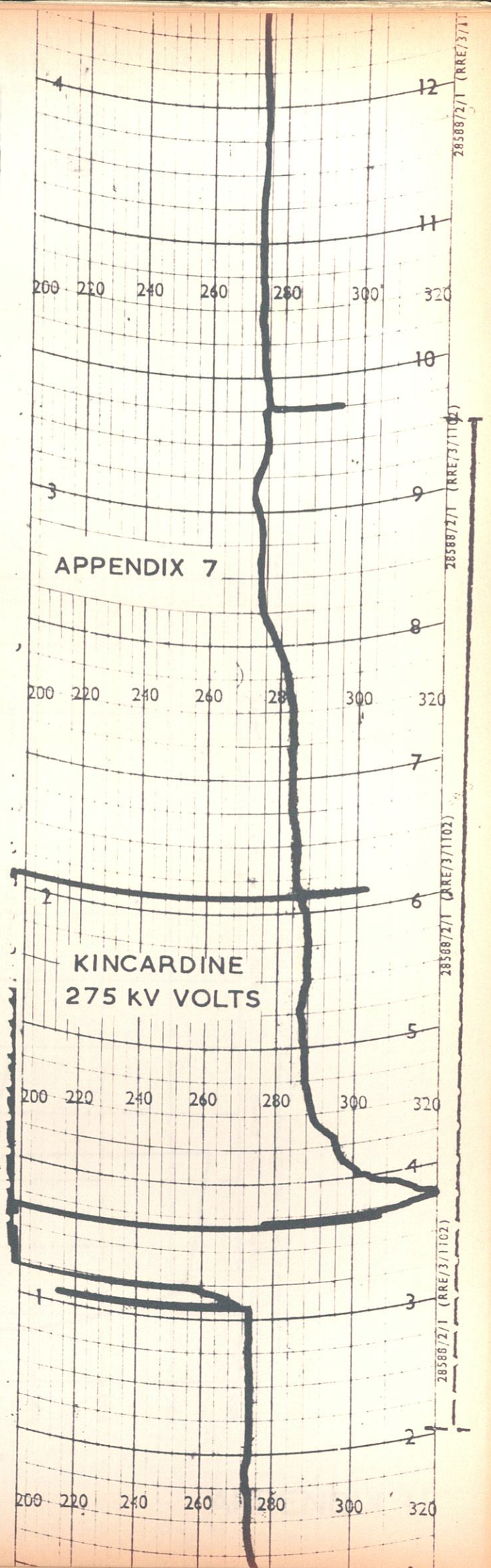
APPENDIX 6

S.S.E.B. AREA DEMAND – MW.



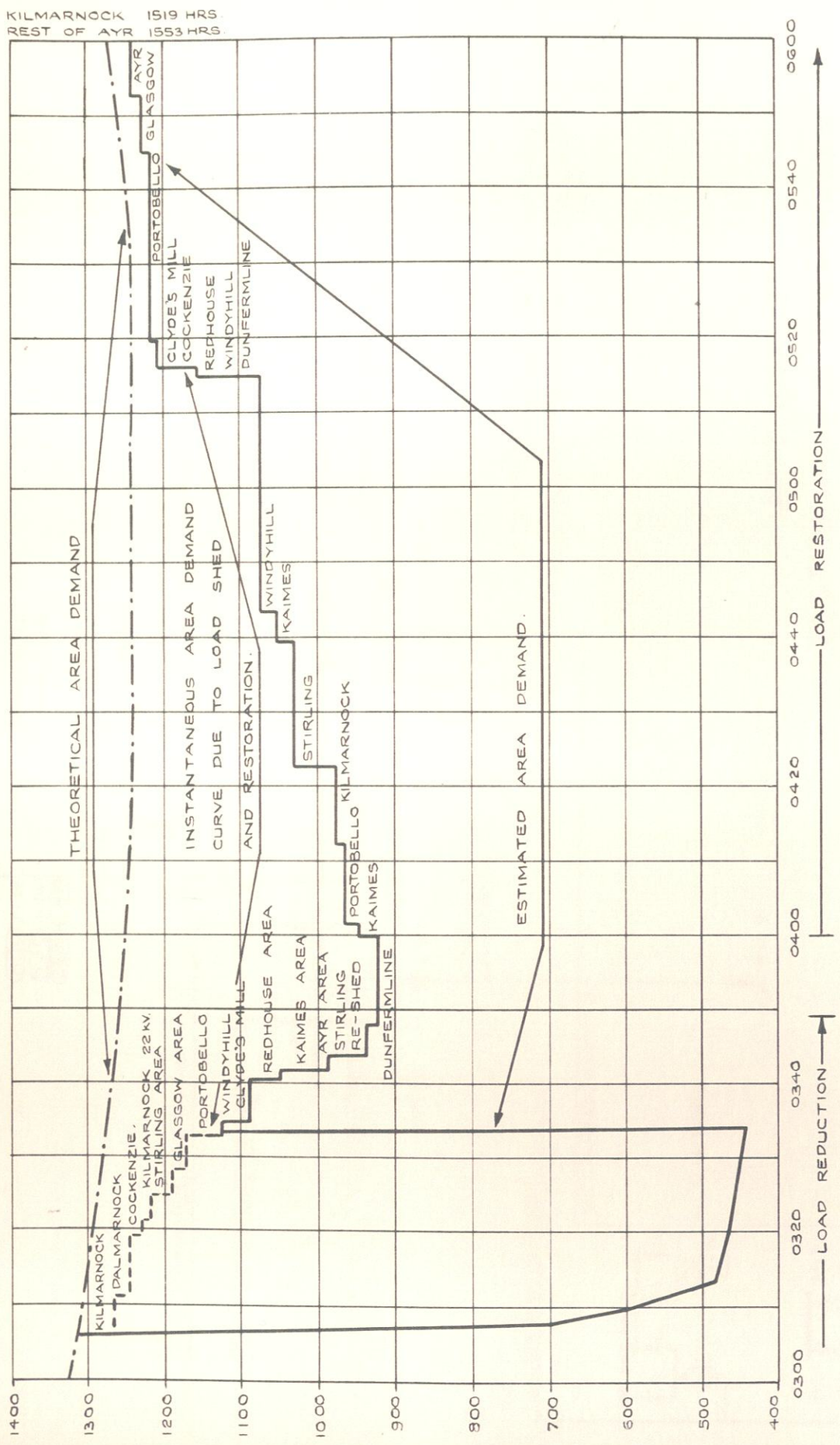
RHB/305/1059 377569-054C


WINDYHILL
275 kV VOLTS
28588/2/1 (RRE/3/1102)
200 220 240 260 280 300 320

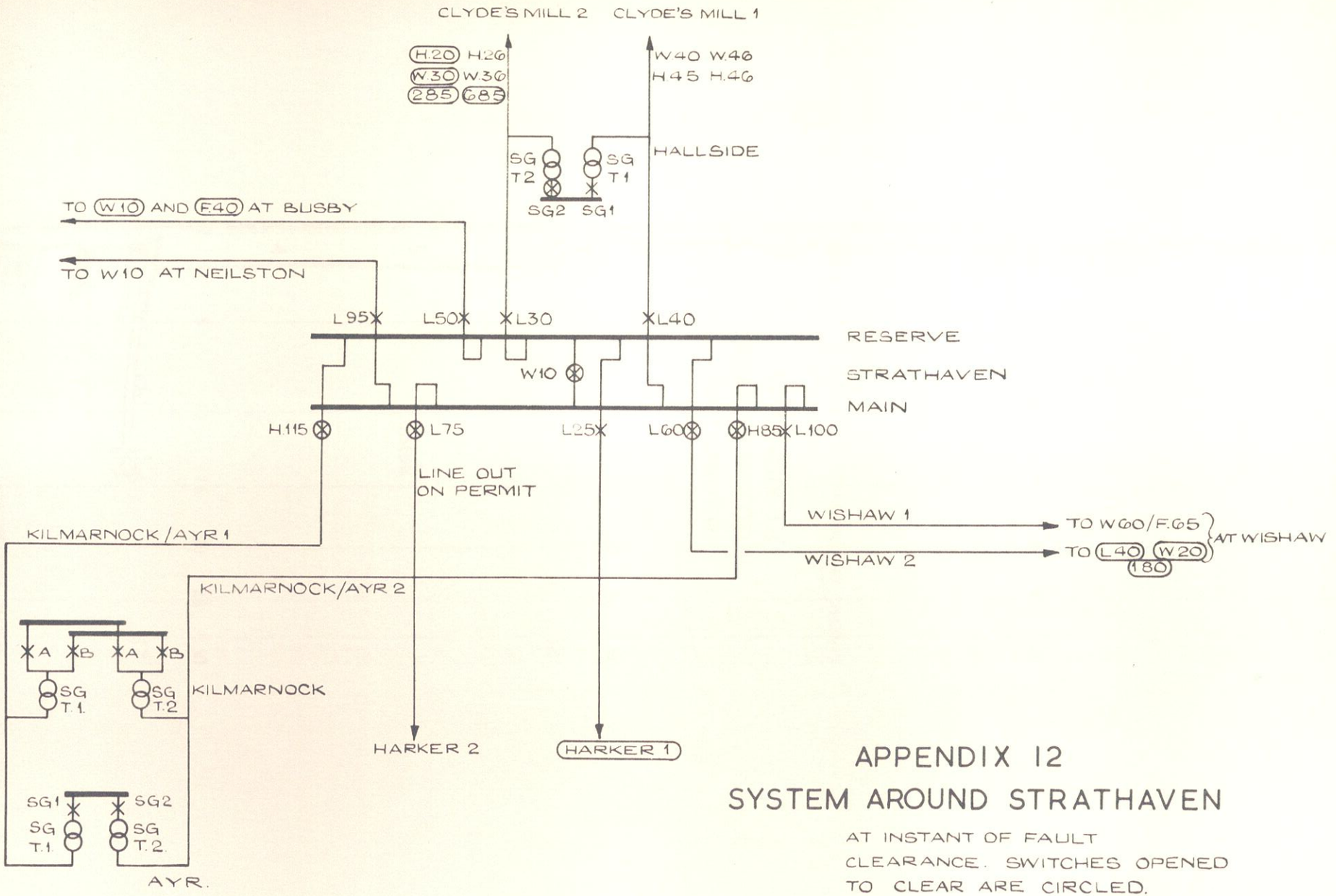

APPENDIX 7
KINCARDINE
275 kV VOLTS
28588/2/1 (RRE/3/1102)
200 220 240 260 280 300 320

KILMARNOCK FAULT - SAT. 8th. NOV. 1969

ESTIMATED REDUCTION IN DEMAND DUE TO LOW VOLTAGE AND LOAD SHEDDING.



APPENDIX 11

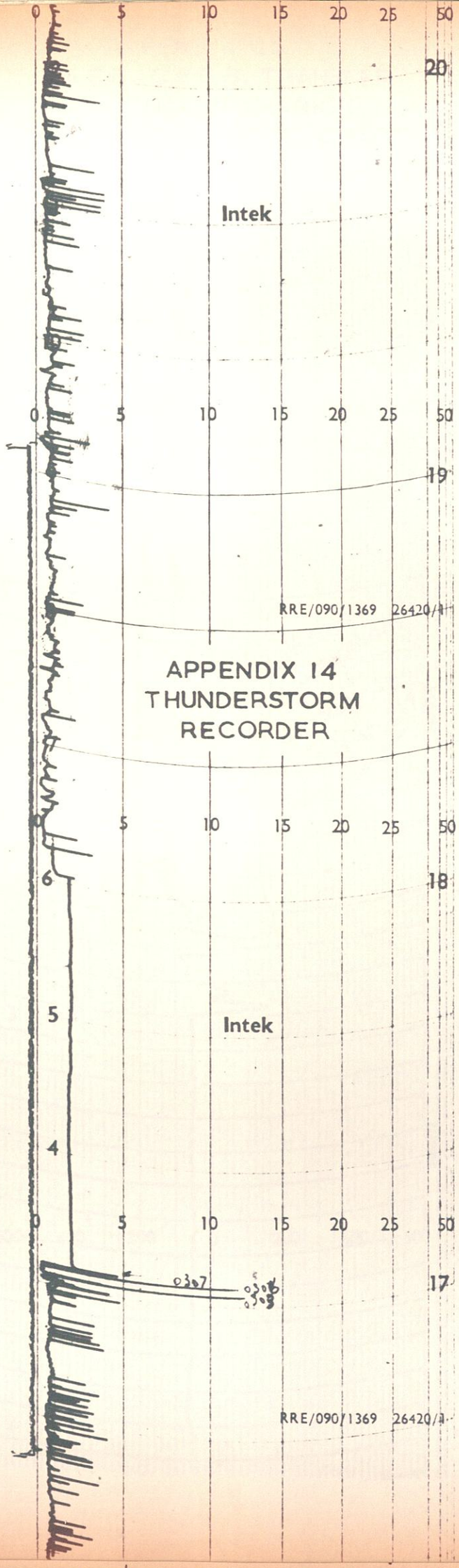


APPENDIX 12

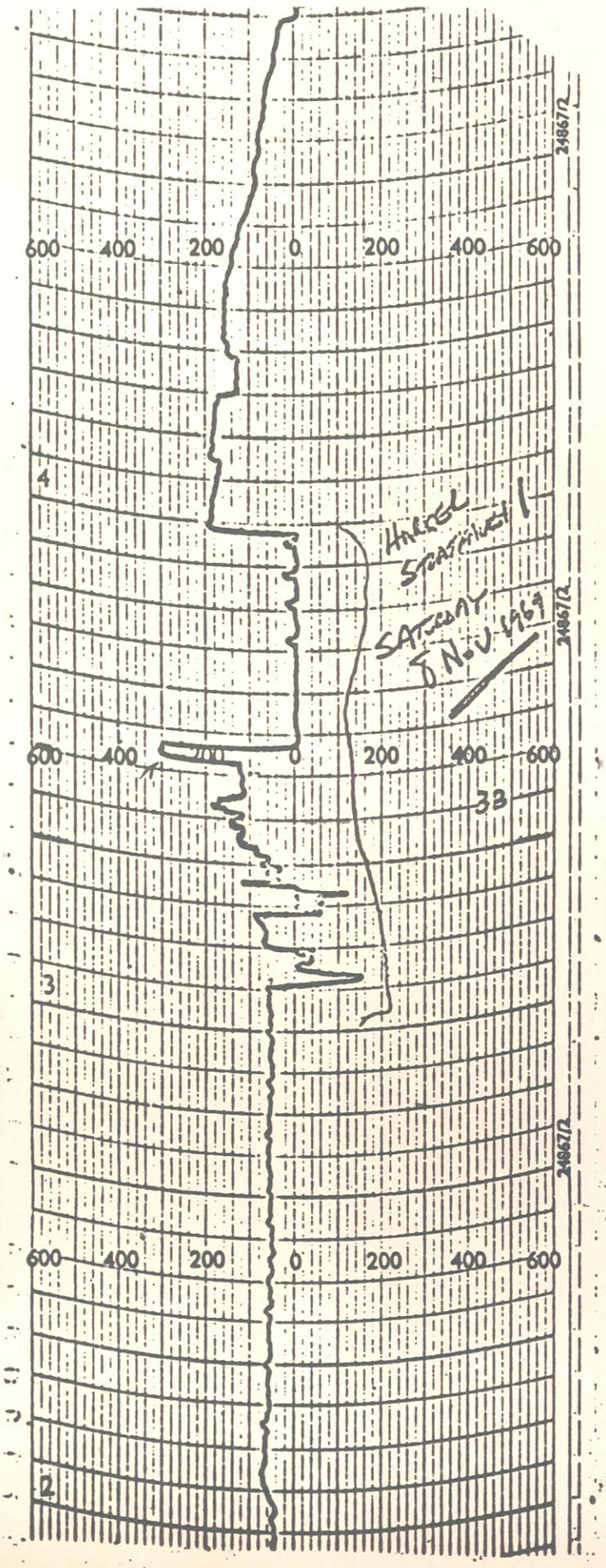
SYSTEM AROUND STRATHAVEN

AT INSTANT OF FAULT
CLEARANCE. SWITCHES OPENED
TO CLEAR ARE CIRCLED.

APPENDIX 12


0 5 10 15 20 25 50
20
Intek
0 5 10 15 20 25 50
19
RRE/090/1369 26420/1
APPENDIX 14
THUNDERSTORM
RECORDER
5 10 15 20 25 50
6
18
5
Intek
4
0 5 10 15 20 25 50
17
RRE/090/1369 26420/1

APPENDIX 15
S.S.E.B. - C.E.G.B. TRANSFER
STRATHAVEN – HARKER I
MANCHESTER G.C.C. CHART



Appendix 1

Report on the Electrical System Fault of Saturday, 8th November, 1969

Conditions prior to the Fault 8th November, 1969

Transfers	C.E.G.B. Programme Float	actual	-28
	H.E.B.	"	-386
Frequency	50.03 Hz.		
Demand	S.S.E.B. demand	1,325 MW.	
	H.E.B.	297 MW.	
	Cruachan Pumping	220 MW.	- 1,842 MW.
Generation	S.S.E.B. + Chapelcross	1,146 MW.	
	H.E.B.	683 MW.	- 1,829 MW.

Plant in S.S.E.B. System

Barony	54
Cockenzie	488
Methil	54
Hunterston	334
Chapelcross	176
Galloway	33
Lanark	14
	1,153
Less 7 MW. at Kincardine =	1,146

Report on the Electrical System Fault of Saturday, 8th November, 1969

Machines Affected during Period of Fault (8.11.1969)

		Non-S.S.E.B. MW.	S.S.E.B. (sent out) MW.
03.06	Tripped at time of Fault:-		
	Cockenzie 2 sets (1-4) N.P.S.		488
	Hunterston 6 sets (1-6) N.P.S. (Reactors tripped manually)		334
03.10	Cruachan 2 sets (2-4) pumping	-220	-
	03.10 Methil 1 set G1 loss of aux. and N.P.S. trip		28
	03.14 Lanark Sets tripped by hand, loss of governor oil		14
	03.15 Methil 1 set G2 unloaded to 5 MW. tripped on N.P.S. protection		26
	03.15 Barony 1 and 2 sets do.		54
	03.18 Blyth 1 set B5 tripped by hand, N.P.S. alarm operated	124	-
	03.20 " 1 set A4 tripped N.P.S.	114	-
	03.20 Chapelcross 8 sets (1-8) tripped, loss of aux.	176	-
	03.20 Carsfad 1 set G1 O/C B phase		6
	03.20 Earlstoun 1 set G1 O/C B phase		7
	03.25 Blyth 1 set A2 tripped by hand, loss of auxiliaries	112	
	03.26 " 1 set B6 tripped by hand, loss of auxiliaries and N.P.S. alarm	180	-
	03.32 Tongland 1 set G3 high volts		9
		706	966
		-220	
		486	

Report on the Electrical System Fault of 8th November, 1969

Station Generation Restoration (approximate times)

		OFF LOAD		ON LOAD		FULL LOAD		ON LOAD REQUEST
Barony	No. 1	0315	8.11.69	0500	8.11.69	0545	8.11.69	0336
	No. 2	"	"	0425	"			
Bonnybridge	No. 7	-	7.11.69	0450	8.11.69	0502	8.11.69	0335
	No. 8	-	"	0445	"			
Braehead	4	-	7.11.9	0530	8.11.9	0550	"	0332
	5	-	"	"	"	"	"	"
	1	-	"	0545	"	0615	"	
	2	-	"	0625	"	0700	"	
	3	-	"	0655	"	0725	"	
Clyde's Mill	10	-	"	0415	"	0530	8.11.9	0340
	12	-	"	"	"	0530	"	
	9	-	"	0445	"	0600	"	
	11	-	"	0500	"	"	"	
	6	-	"	0525	"	0810	"	
	7	-	"	0525	"	0730	"	
	5	-	"	0600	"	0730	"	
	8	-	"	0615	"	"	"	
		On load						
Cockenzie	1	0308	8.11.9	1000	8.11.9	1140	9.11.9	0336
	3	Barring		1015	9.11.9	2200	"	(on R & M)
	4	0308	8.11.9	0550	11.11.9	1400	11.11.9	
Dalmarnock	1	-	7.11.9	0525	8.11.9	0630	8.11.9	0345
	8	-	"	0502	"			
	9	-	"	0445	"			
Dunfermline	2	-	7.11.9	0426	8.11.9	0430 - 45 MW. 0530 - 62 MW.		0320
	3	-	"	0405	"	0410 - 45 MW. 0600 - 45 MW.		"
Tongland	1	On load		0332	8.11.9	0332	8.11.9	0320
	2	at time		"	"	"	"	
	3	of incident		0334	"	0335	"	
Glenlee	1	"		0332	"	0334	"	
	2	"		"	"	"	"	
Kendoon	1	11 MW.		-		-		Stayed on load
Kendoon	2			0454	"	0455	"	
Earlstoun	1			0454	"	"	"	
	2			0414	"	0415	"	
Carsfad	1			0414	"	"	"	
	2			0534	"	0535	"	
Hunterston	1	0307	8.11.9	2323	"			0336
	2	"	"	2339	"	0830 (9.11.9) 136 MW.		
	3	"	"	0440	9.11.9	2125 (10.11.9) 278 "		
	4	"	"	1525	10.11.9			
	5	"	"	1832	"	0800 (11.11.9) 300 "		
	6	"	"	1719	"	1230 (11.11.9) 320 "		

Kilmarnock/

Appendix 3 (Contd.)

		OFF LOAD		ON LOAD		FULL LOAD		ON LOAD REQUEST
Kilmarnock	1	-	7.11.9	0530	8.11.9	)		
	2	-	"	0626	"	)0700	8.11.9	0310
Kincardine	1	0206	8.11.9	0707	"	0850	8.11.9	0320
	2	2332	7.11.9	0605	"	0850	"	
	3	0010	8.11.9	0834	"	0915	"	
	4	2358	7.11.9	0644	"	0730	"	
Methil	1	0310	8.11.9	0905	"	0945	8.11.9	0320
	2	0315	"	0844	"	0915	"	
Pinkston	1		7.11.9	0520	"	0555	"	0322
	5		"	0545	"	0715	"	
Portobello	2	0015	8.11.9	0355	8.11.9	0425	8.11.9	0330 and
	3	2345	7.11.9	0610	"	0730	"	0500 (Cold Start)
	6		"	0725	"	0800	"	0455
	7		"	0750	"	0830	"	"
Yoker	9		7.11.9	0600	"	0630	"	0345 and
	8		"	0630	"	0700		0420 (Cold
	7		"	0700	"	0830	"	Start)
	6		"	0730	"	1000	"	
		On load						
Bonnington	1	0312	8.11.9	0345	"	0346	8.11.9	None
	2	0314	"	0420	"	0422	"	
Stonebyres	1	0316	8.11.9	0415	"	0416	"	None
	2	0315	"	0355	"	0356	"	
							8.11.9	
Chapelcross	5	0318	8.11.9			)0930 - 20 MW.		
	6	"				)1200 - 77 "		
	1	"				)1400 - 87 "		
	8	"				)1600 - 163 "		
	7	"				)1630 - 169 "		
	4	"				)		
	3	"				)		
	2	"				)		

APPENDIX IV

275 kV. System Fault - November 8th, 1969

By the Chief Engineer Generation Operation

Summary

At 03.06 a lightning strike on the Strathaven/Kilmarnock No. 1 275 kV. circuit created a fault condition on the system which failed to clear because of the maloperation of a tripping relay at Strathaven.

Prior to the fault the total S.S.E.B. and H.E.B. demand with 220 MW. of Cruachan pumping load was 1,842 MW. S.S.E.B. generation 970 MW., Chapelcross 176 MW. and H.E.B. 683 MW.

Within 10 minutes of the lightning strike the S.S.E.B. had lost 700 MW. of generation and within 20 minutes all generation except No. 1 set at Kendoon (11 MW.). With the exception of Earlstoun, Carsfad, Tongland all the other generators tripped on negative phase sequence protection. Earlstoun and Carsfad tripped on overcurrent protection and Tongland on over-voltage. Lanark sets were manually tripped when the governor oil motors tripped on protection. During this period the H.E.B. lost 387 MW. of generation and Chapelcross 176 MW.

The subsequent low voltage on the system was reducing demand and the C.E.G.B. transfer was over 1,000 MW. (indicator was off scale).

At this point Distribution Control Centres were told to cut demand by 50%. The C.E.G.B. transfer dropped to under 1,000 MW. H.E.B. were instructed to give maximum generation and S.S.E.B. restoration commenced. The bulk of the restoration was completed by 05.00 hours.

Conditions Prior to Fault

Details of conditions prior to the fault are given in Appendix 1.

The frequency was 50.03 cycles/second.

Transfers of power were: (C.E.G.B. (Programme "float")) actual -28
(H.E.B. -386

Station Generation Restoration

By 03.32 all S.S.E.B. generation was off load with the exception of one 11 MW. set at Kendoon.

From 03.20 onwards as required by Grid Control, stations were called upon to get back on load as quickly as possible.

Appendix 3 gives details of the restoration of generation at each station.

Conditions during Period of Fault

Although the start of the fault can be given as 03.06 on 8th November, 1969 following a lightning strike on the Strathaven/Kilmarnock No. 1 line, the duration of the fault is not certain. From 03.34 when the Strathaven/Harker No. 1 line was disconnected, the S.S.E.B. system began to stabilise. Details of plant affected are given in Appendix 2.

Main/

Main Events in Stations during the System Fault

The following are difficulties experienced by stations following the complete loss of A.C. supplies.

Details are given in Appendix 4.

1. Damage to Plant

The only known damage to plant that can be directly attributed to the system disturbance are a number of burned out contactors, trip coils and fuses at Braehead and Cockenzie.

At Cockenzie on No. 3 set, the condenser tubes were pierced by the failure of the diffuser which fell onto the tube nest, probably due to the vibration set up when the turbine was suddenly de-loaded.

Because of the possible effects of overheating on the alternator rotors at Cockenzie when they were subjected to negative phase sequence currents consideration is being given to examination of the alternators during the 1970 annual overhaul.

At Hunterston three control rod indicators failed when the rods operated on reactor shutdown.

2. Loss of Generation

With the exception of Kendoon No. 1 set (11 MW.) all plant on load at the time of the fault came off load due to protection operation (966 MW.). Most tripped on negative phase sequence protection with the exception of:- No. 3 set at Tongland due to overvoltage and No. 1 at Carsfad and No. 1 at Earlstoun due to overcurrent; others were tripped by hand - see Appendix 2.

3. Voltage Variation

Most stations experienced large over and under voltage variations on both the station and plant auxiliary busbars.

In one case the auxiliary board voltage fell from 3.3 to 1.1 kV. Under-voltage had the effect of raising the current on running motors and in most cases to the point where the overcurrent protection operated.

Voltage fluctuations caused much delay where auxiliaries would not start or tripped on protection, i.e. under voltage and overcurrent.

4. Frequency Variation

At Grid Control the minimum frequency indication was 49.5 cycles/sec. At 8 stations the frequency indication varied between 49 and 47 cycles/second, probably due to voltage variations. Dalmarnock (48.8), Dunfermline (48.5), Galloway (49), Methil (48), Pinkston (47.5), Portobello (47), Yoker (49) and Lanark (47).

5. Loss of Auxiliary Supplies

All stations, except the Galloway Hydros, lost electrical supplies to auxiliary motors by either failure of all A.C. and/or auxiliary boards or by the operation of motor undervoltage or overcurrent protection.

Stations/

Stations that lost auxiliary board supplies:-

Barony (3.3 KV), Cockenzie (415 V), Dalmarnock (Grid), Dunfermline (3.3 kV), Kilmarnock (Grid), Kincardine (415 V), and Pinkston (33 kV. station supply).

Stations that lost motor drives due to voltage fluctuations and low voltage causing overcurrent protection to operate:-

Barony, Bonnybridge, Braehead, Clyde's Mill, Cockenzie, Dunfermline, Hunterston, Kilmarnock, Kincardine, Methil, Portobello, Yoker and Lanark.

6. Emergency Electrical Supplies - Diesel-generators and Batteries

Where diesel-generators are installed, other than the Clyde's Mill and Dunfermline gas turbine stations, they are for the purpose of supplying emergency lighting or power to vital auxiliary drives or both.

At the gas turbine stations they also supply power to shutdown and start-up the plant when all other A.C. supplies have failed.

At Barony, Bonnybridge, Dalmarnock, Dunfermline, Hunterston, Methil and Pinkston the diesel-generators operated correctly manually, and at Cockenzie on automatic.

Diesel-generator No. 1 at Hunterston when synchronising onto the diesel board tripped on reverse current and could not be restarted due to the low air pressure. Diesels Nos. 2 and 3 operated successfully. Kincardine No. 1 diesel-generator failed to start automatically because the cooling water high temperature protection operated for some unknown reason and was therefore manually started, Nos. 3 and 4 did not automatically start because the A.C. auxiliary board supply switch did not trip on undervoltage and were therefore manually started. All diesel-generators had operated successfully when tested a week earlier.

The Portobello diesel-generator was successfully started manually but the auto-changeover switch to the auxiliary board failed to operate when the switch control circuit fuse blew. This had never previously occurred.

At Braehead it is intended giving the station battery charger a boost supply from the diesel-generator to prevent the battery being overloaded.

The diesel-generators proved invaluable in getting plant back on load in the minimum of time.

Generation Operation Division should investigate at what point automatically controlled diesel-generators should operate, on complete loss of A.C. supplies or at some predetermined undervoltage setting.

7. Gas Turbine Stations

The 50 MW. gas turbine at Clyde's Mill was not available because of a breakdown at the time of the incident. Both gas turbines at Dunfermline were off load and available for 70 MW. each.

On being requested to generate the Switchboard Attendant initiated barring of the sets prior to starting but almost simultaneously A.C. auxiliary supplies to the gas turbine building were lost and the starting sequence did not operate.

As/

As a consequence of the A.C. supply failure, initiation of the barring virtually simulated a fault condition on the machines causing the D.C. auxiliaries to start and the field circuit breakers to open.

It was decided at this stage to start up using the emergency diesel but a time loss of 15 mins. due to the above factor occurred.

At 03.30 3A engine tripped on high turbine entry temperature due to a faulty fuel distributor. No. 3 G.T. was available for synchronising at 03.40 but it was found that the grid volts were rising rapidly and the machine could not be synchronised until 04.05. No. 3 set reached 45 MW. at 04.10. (30 MW. at 04.32 when 'B' engine was lost due to high entry temperature).

No. 2C engine tripped on "flame out". No. 2 G.T. was started at 04.05 hrs. on normal auxiliary supplies being restored but the machine failed to auto-synchronise, it is thought due to fluctuating busbar voltage. The machine was synchronised at 04.26 hours. No. 2 set reached 62 MW. at 05.50. (45 MW. at 04.46).

Note: The diesel generator is designed to start one gas turbine at a time.

8. Hydro Stations

At the time of the incident the following sets were on load in the Galloway scheme:

Tongland No. 3	11 MW.
Earlstoun No. 1)	
Carsfad No. 1)	24 MW.
Kendoon No. 1)	

All, except Kendoon No. 1, tripped on either overcurrent or under-voltage protection.

Kendoon No. 1 generator remained on the bars throughout the disturbance and was running normally when seen at 04.00 hours, with 13 MW. and 6 MVAr leading. Remote indications during the disturbance showed MVArs off the scale lagging, with zero MW., and 580 stator amps - all reading steadily in spite of fluctuating conditions.

This may have been due to Dictum disturbance, a number of alarms having been signalled when the incident began, or the machine may have come down to no-load (for no apparent reason) - this being a possible reason for not tripping on O/C as at Earlstoun and Carsfad. Switchgear and motor protection settings are the same at all stations.

It should be noted however that remote full load indications were normal after 03.32 hours.

Tongland sets Nos. 1 and 2, full load at 03.32 and No. 1 at 03.35. Glenlee Nos. 1 and 2 could not be synchronised at 03.20 due to low and unstable busbar voltage.

Kendoon No. 2 on full load at 04.55.

Earlstoun No. 2 on full load at 04.15 and No. 1 at 04.55 as requested by Grid Control.

Carsfad/

Carsfad No.2 on full load at 04.15. No. 1 at 05.35 after a 40 minutes delay due to attempting to start-up before previous shutdown had been fully completed.

For about 30 minutes after the fault started the Control Engineer could not get through to the Grid Control Engineer because the telephones were engaged and the VHF radio failed.

At the time of the incident the Lanark sets were on load as follows:-

Stonebyres	No. 1)	5 MW.
"	No. 2)	
Bonnington	No. 1)	8.5 MW.
"	No. 2)	

All sets were manually tripped when the governor oil pumps tripped on overcurrent protection.

30 minutes were lost when running up No. 2 set at Bonnington when a turbine guide vane link broke and had to be replaced.

Sets were put back on load as soon as busbar voltage allowed - see Appendix 3.

9. Communications

For about 30 minutes Barony and Tongland could not get through to Grid Control because the telephone lines were engaged.

At Bonnybridge the G.P.O. line became overloaded by consumers calls.

The Dalmarnock telephone alarms failed.

Also at Dalmarnock and Tongland the VHF radio emergency line to Grid Control failed when the A.C. supply failed.

Clyde's Mill and Dalmarnock radio phones went out of action when the A.C. supply for the transmitter in the Control Room failed.

The above are under investigation.

10. Load Shedding

Details of load shedding at power stations are given in Appendix 5.

With the exception of Barony and Portobello load shedding occurred either because of automatic protection operation or upon instruction of Grid or Area Control.

Barony reduced generation to avoid overloading the local feeders.

Portobello Control Engineer carried out Emergency Procedure 15A, tripping feeders when the indicated frequency fell below 48.5 cycles/sec.

11. Nuclear Stations/

11. Nuclear Stations

Hunterston lost 334 MW. between 03.05 and 03.07. The voltage to the auxiliary boards did not stabilise until 03.35, thereby delaying re-energising motor auxiliaries. The on-load times for the sets etc. are given in Appendix 3.

Reactor 'A' and sets 1, 2 and 3 went back on load normally.

Reactor 'B' had to be depressurised to replace three defective control rod indicators, this took 24 hours approximately.

At 21.25 on the 10th November the load was 278 MW. and set 4 was taken off load to repair the float valve in the clean drains tank.

At 08.00 on the 11th November the load was 300 MW.

Chapelcross (A.E.A.) lost 176 MW. on eight sets by 03.18 and was back to 169 MW. at 16.30 on 8th November. There was no damage to plant or major delays.

Difficulties and Causes of Delays in Reinstating Generation

1. The effect of voltage fluctuations on auxiliary supplies was a major cause of lost time due to motors tripping out on protection, either under-voltage or overcurrent.

2. Changeover of auxiliary electrical supplies from main to emergency diesel generators and back again.

3. In the large stations, including Hunterston, checking out automatic control systems on such things as C.W., boiler air controls and milling plant and resetting interlock controls before boiler and turbine auxiliaries could be started caused further delays.

4. With the run down in numbers of shift personnel in anticipation of the introduction of productivity schemes, difficulties and delays were experienced in a number of stations in dealing with the emergency situation and the subsequent running-up of plant.

   In certain cases this was aggravated because some of the staff had not long been in post and were inexperienced.

5. The stopping of the turbine barring for a period between the loss of the A.C. supply and the starting of the diesel generator was probably the cause of vibration during the run-up of No. 3 sets at Kincardine.

   Vibration was also experienced on No. 1 set at Pinkston at about 7 MW. which also may have been caused by the barring gear stopping. Pinkston has no emergency supply.

6. In two cases over enthusiasm to get all plant up to full load quickly with the limited manpower resources available during the night, may have slightly lengthened the overall time.

7. Looking at Appendix 3 which gives details of generation restoration one notices that stations with large units operating at high temperature and pressure were the slowest in getting back to/

to full load after the emergency shutdown. On the other hand Kincardine which was off load, on "hot standby" but ready to run had a 200 MW. set at full load by 07.30 and two 120 MW. sets at full load by 08.50.

The hydros and the 20 to 60 MW. steam sets not being too sensitive to fast "run-up" and rapid loading allowed the electrical system to be stabilised by 05.00.

Report on the Electrical System Fault 8th November, 1969

Station	Load & Plant Conditions at Time of Fault	Generator Tripping Initiation	Other Items Tripped	Auxiliary Supply Network	Load Shedding	"Indicated" Frequency Variation	"Indicated" Voltage Variation	Other Alarms & Abnormal Conditions	Load Reinstatement (Request (a) Actual (b)) Full Load (F/L)	Cause of Delays in Reinstating Generation	Plant Damage	Difficulties etc.
	1	2	3	4	5	6	7	8	9	10	11	12
Barony	No.1-28 MW. No.2-26 MW.	Negative Phase Sequence	All 3.3 kV. main auxiliaries tripped on thermal rela	The 3.3 kV. Motor Auxiliaries tripped on thermal overload. Diesel generator started manually. Voltage low & fluctuating. Diesel generator started manually.	None. Generation reduced to meet local feeder maximum currents	50 to 49.5	33 to 15 kV	As the voltage fell . feeder & plant currents rose.	a-0336 b-No.2-0425 No.1-0500 F/L-0545	None.	None.	Telephone lines to Grid Control engaged for 25/30 minutes.
Bonnybridge	Off load	-	-		None.	51 to 49	132 to 75kV	T2B alarm on tap changer.	a-0335 b-No.8-0445 No.8-0450 F/L-0502	Low auxiliary voltage and tripping of auxiliaries on over current.	None.	T2B alarm "tap change out of step". I.D. fans tripped due to voltage fluctuations causing over current. GPO overloaded by consumer calls.
Braehead	Off load all turbines on barring.	-	-	3.3kV auxiliary board volts down to 1.1kV. Diesel generator did not operate on auto, but started manually.	None.	50 to 49.4	132 to 80kV Neilson/ Renfrew phase loads unbalanced		a-0332 b-No.4-0530 No.5-0530 No.1-0545 No.2-0625 No.3-0655 F/L-0725	Voltage surges until 0335. Motors tripped on over current. Wet coal in feeders & chutes. Low boiler steam pressure.	Auxiliary oil pump motor trip coils burned out	Station battery almost over loaded by auxiliary load. Battery charger to be fitted with a supply from the diesel generator. High eccentricity on the turbine
Clyde's Mill	Off load. Turbines on barring	-		Voltage low and fluctuating. Diesel generator not used, but available.		50 to 49.4	-		a-0340 b-No.10-0415 No.12-0415 No. 9-0445 No.11-0500 6/7-0525 No. 5-0600 No. 8-0615 F/L-0810	Time lost in starting fans due to the low voltage & motors tripping on over current protection.	None.	Emergency lighting did not automatically start because the AC supply did not completely fail. Pocket phones failed during low voltage period, (AC supply).
Cockenzie	No.1-240MW No.4-280MW No.3-off load No.2-breakdown	Negative phase sequence	Some motor auxiliaries lost, AVR, condensate flow, stator water failed, compressor low air pressure alarm.	Low auxiliary voltage, 11 kV. to 7 kV. Diesel Generator operated on auto. Lost 415V. motor auxiliaries on over-current.	33kV local feeders, 275 & 33kV switched out by Charge Engineer.	50 to 49.6	11kV to 7kV	-	a-0336 b-No.1-1000 9/11/9 No.3-1015 9/11/9 No.4-0550 11/11/9 F/L-1-1140 9/11/9 3-2200 9/11/9 4-1400 11/11/9	Station transformer hand tap changed. Switching on 11 kV auxiliary boards. Re-establishment of plant auxiliaries etc. fuses had to be replaced on the valve starter board. Motors tripped on over current. No.1 delayed 110 mins. due to turbine metal temp. differentials. No. 3 delayed due to high silica.	Fuses & condenser tube failures. 415V transformer & lighting contactor burned out	B.F.P. failed to start on 9kV due to over current. No.1 drum water level low. Interceptor valve seized. Various dampers & controls hand reset. 415V. board overloads had to be reset. No.3 condenser tube failures. No.4 same as No. 1. 33kV switches could not be re-closed due to low air pressure.

NOTE: Diesel generators only provide emergency lighting and power for essential auxiliaries.

Dalmarnock/

Station	Load & Plant Conditions at Time of Fault 1	Generator Tripping Initiation 2	Other Items Tripped 3	Auxiliary Supply Network 4	Load Shedding 5	"Indicated" Frequency Variation 6	"Indicated" Voltage Variation 7	Other Alarms & Abnormal Conditions 8	Load Reinstatement (Request (a) Actual (b) Full Load (F/L) 9	Cause of Delays Reinstating Generation 10	Plant Damage 11	Difficulties etc. 12
Dalmarnock	Off load. Turbines on barring.		All auxiliaries lost the 132 kV. station transformers opened by the Control Engineer (Operation Memo 15A)	Diesel Generator started manually	All local feeders switched out.	50 to 48.8	132kV rose to 152kV. 33kV distribution feeder voltage dropped to 21.5kV	-	a-0345 b-No.9-0445 8-0502 1-0525 F/L-0630	-	None.	Radio phones & telephone alarms out of commission during incident. VHF radio to grid failed (AC supply)
Dunfermline	Off load	-	Field switch opened.	All 415V auxiliary boards lost due to Auxiliary transformers tripped on under voltage protection. Diesel generator hand started.	Calais feeders opened.	50 to 48.5	158kV on 132 system down to 60 kV.	Gas turbine AC failure alarm. Main station fault alarm. Field switch opened. Voltage control fault on 132 kV. T1 and T2.	a-0320 b-No.3-0405 No.2-0426 No. 2(45MW) 0430 " (62 ") 0530 No. 3(45 ") 0410	15 mins.lost due to AC failure after starting gas turbine. 25 minutes lost due to voltage fluctuations when synchronising.	None.	Soon after starting the gas turbine sequence AC supply failed indicating a fault. Diesel generator started satisfactorily. No.3 gas turbine tripped at 45MW due to faulty fuel distributor.
Galloway	No.3 Tongland 11 MW load No.1 Earlstoun No.1 Carsfad No.1 Kendoon 25 MW between them	Earlstoun & Carsfad tripped on over current. Tongland on over voltage. Kendoon No. 1 did not trip.	-	-	-	50 to 49	11kV board voltage varying from 12 to 6kV. 132 fell to 75kV.	-	a-none b-Tongland 1 & 2 0332 No.3-0335 Glenlee No.1 & 2 0332 Kendoon No.2-0455 Earlstoun No.2-0415 No.1-0455 Carsfad No.2-0415 No.1-0535	Glenlee busbar voltage fluctuating & surging. Carsfad No.1 delayed 40 minutes due to trying to start up before shut down sequence completed.	None.	Between 0149 & 0248 Blackwater/ Carsphairn tripped & auto reclosed 8 times. All stations stayed on grid. From 0307 to 0332 Tongland could not get through to grid control owing to lines being engaged
Hunterston Kilmarnock/	On load 334MW All generators	Generators tripped on negative phase sequence	Generator No. 3 transformer Buchholz trip operated. 2B gas generator B.F.P. & C.W. pumps tripped on over current. Reactors tripped manually. Gas circulators tripped on 'no volt' protection. Turbines Nos. 4 & 5 tripped on low vacuum.	Motors tripped on over current. Diesel Generators started.	None.	-	132 fell to 80 kV & 415 to 200V.	Saltcoats feeder.	a-0336 b-1-2323 8/11/9 2-2339 8/11/9 3-0440 9/11/9 4-1525 10/11/9 5-1832 10/11/9 6-1719 10/11/9 F/L-1230 11/11/9	Reactor B depressurised to replace 3 faulty control rod indicators, 24hr. delay. Turbo Alternator 4 delayed 5 hours to repair a clean drains tank valve.	3 control rod indicators damaged.	No.3 generator AVR fault. 1 diesel generator tripped on reverse current when synchronising - low volts on bus bars. CCR frequency meter faulty.

Station	Load & Plant Conditions at Time of Fault 1	Generator Tripping Initiation 2	Other Items Tripped 3	Auxiliary Supply Network 4	Load Shedding 5	"Indicated" Frequency Variation 6	"Indicated" Voltage Variation 7	Other Alarms & Abnormal Conditions 8	Reinstatement (Request (a) Actual (b)) Full Load (F/L) 9	Cause of Delays Reinstating Generation 10	Plant Damage 11	Difficulties etc. 12
Kilmarnock	Off load	-	T1 & T2 switched out by Control Engineer at 0322. 0413 grid said reclose T1 & T2.	All auxiliaries lost, when Control Engineer switched out station. 132 kV. supplies when voltage fell to zero. (Operation Memo. 15A)	None.	-	-	-	a-0310 b-No.1-0530 No.2-0626 F/L-0700	Fluctuating busbar voltage 30 minutes delay.	None.	No diesel generator for emergency lighting etc. T1 & 2 closed and station busbar voltage fell to 26kV because T2 tap-changer failed to operate, therefore T2 was taken off load.
Kincardine	Off load Turbines 1,2 3 and 4 on barring.	-	-	Loss of 415V auxiliaries. Diesel generator did not start automatically, manually started	None.	50 to 49.5	275 fell to 260kV. 132 fell to 80 kV. 415V boards up to 500V.	Voltage restraint on feeders 132kV. Faulty protection pilots.	a-0320 b-No.2-0605 4-0644 1-0707 3-0834 F/L-No.4-0730 1-0850 2-0850 3-0915	Air heater hand barred for a period. Boiler auto controls & compressors lost. Time lost due to having to reprime C.W. system. No.3 turbine experienced vibration. No.4 barring by hand for 20 mins. due to loss of a motor supply. No.1 barring motor over load protection isolated in order to start up motor.	None.	Loss of control room switchgear indication. Diesel generators failed to auto start. Manually operated. One boiler was delayed because at the time of fault it was undergoing minor maintenance.
Methil	On load 54MW	Negative phase sequence	-	Low auxiliary board voltages. Boiler auxiliaries tripped on under voltage and some on over current. Diesel Generator manually started.	None.	50 to 48	33kV fell to 20kV	-	a-0320 b-No.1-0905 No.2-0844 F/L-0945	Plant checks, C.W. priming, reinstating auxiliaries.	None.	Some delay due to the Shift Engineer being new to the job. The boiler operator was also new to the job. (There are only 2 operators for 2 boilers & 2 turbines which slows down the return of the units under emergency conditions.)
Pinkston Portobello/	Off load No.1 Turbine on barring	-	-	All auxiliary boards lost when station 33 kV supply failed. Diesel generator operated manually.	None.	50 to 47.5	6kV system dropped to 2.1kV	-	a-0322 b-No.1-0520 No.5-0545 F/L-No.1-0555 5-0715	Loss of barring on No. 1 set. No emergency supplies. Vibration at 7MW on No. 5 set.	None.	-

Station	Load & Plant Conditions at Time of Fault	Generator Tripping Initiation	Other Items Tripped	Auxiliary Supply Network	Load Shedding	"Indicated" Frequency Variation	"Indicated" Voltage Variation	Other Alarms & Abnormal Conditions	Load Reinstatement (Request (a) Actual (b) Full Load (F/L)	Cause of Delays Reinstating Generation	Plant Damage	Difficulties etc.
	1	2	3	4	5	6	7	8	9	10	11	12
Portobello	Off load. Turbines Nos. 2 & 3 on barring	-	-	Auxiliaries lost. Diesel generators started but change over contactor failed due to control circuit fuse failure.	Stage 3 Group 1 instituted. 33 and 11kV feeders opened	50 to 47	6.6kV auxiliaries voltage fell to 5.1kV	-	a-0330 & 0500 b-No.2-0355 No.3-0610 No.6-0725 No.7-0750 F/L-0830	Generator 3 was delayed due to its having been steam cooled for repair work on the Saturday	None	All 4 control room frequency meters operating erratically.
Yoker	Off load	-		Motors tripped on over current	None. Knightswood line shedding relay did not operate.	50 to 49	11kV auxiliaries board varied from 12 to 7 kV	Windyhill/ Partick No.1 intertrip alarm. 110V battery charger fault alarm	a-0345& 0420 b-No.9-0600 8-0630 7-0700 6-0730	30 minutes lost because boiler turbine auxiliary supply failed at 0330	None	-
Lanark Bonnington	Nos.1 & 2 on load 9MW	Turbines tripped manually following loss of governor oil pump	Earth leakage alarm on sets	Major voltage surges on auxiliary boards	None	50 to 47	-	-	a-none b-1-0345 2-0420	30 minutes lost on No. 2 set due to turbine control vane link failure	None	-
Stonebyres	Sets 1 & 2 on load 5MW	Tripped by hand at 0315 and 0316 following loss of governor oil pumps	Earth leakage alarm operated.	Major voltage surges on auxiliary boards	None	50 to 47	-	-	a-none b-No.1-0415 2-0355	-	None	-

4th December, 1969
JJP/LMcA

APPENDIX V

North of Scotland Hydro-Electric Board

Report of Events on H.E.B. System during
System Disturbance on Saturday, 8 November 1969

1. System Conditions Prior to Fault

1.1 Generators on Load

Because of high run-off it was necessary to generate 579 MW. overnight on hydro plant. This together with the output from Carolina Port 'B' (104 MW.) gave rise to high, but not critical line loadings in the South East section of the H.E.B. Area.

The plant capacity on the bars and the load on the generators are given in Appendix 1.

Dounreay was not connected to the main system because of a meteorological forecast of imminent gales.

1.2 H.E.B./S.S.E.B. Transfer

The export to the S.S.E.B. at 03.00 hrs. was 386 MW. and was distributed at the transfer points as follows:-

Abernethy	79 MW.
Bonnybridge	107 MW.
Helensburgh	12 MW.
Kincardine	86 MW.
Strathleven	12 MW.
Windyhill	90 MW.
	386 MW.

2. Operations during and immediately after Fault

2.1 Generation

Between 03.06 hrs. and 03.40 hrs. 387 MW. of generating plant tripped. The incidence of the loss of capacity and the protection indications are given in Appendix 2.

Between 03.25 hrs. and 05.30 hrs. a total of 894 MW. of generating plant (including 200 MW. at Cruachan) was brought on load. The sequence of synchronising and cumulative MW. total are given in Appendix 3.

2.2 Transmission

Six transmission lines tripped during the fault. Switch operations are detailed in Appendix 4.

2.3 Cruachan

Cruachan Sets 2 and 4 were pumping when at 03.10 hrs. negative phase sequence alarms were indicated on both sets. The sets appeared to be labouring unduly and were shut down manually on "Emergency Stop".

At/

At 03.11 hrs. the cooling water and oil pumps on both Cruachan Main Transformers tripped on overload. This in turn operated the intertrip between Cruachan and Dalmally tripping the line switches L15 and L25 and the bus coupler S10 from Dalmally. Inverawe generator, which is controlled from Cruachan, tripped at 03.12 hrs.

The Emergency Diesel failed to start by remote control and when started locally only ran for some ten minutes. Since it had run up with its auxiliaries fed from the unbalanced external supply the fuel boost pump, air compressor and flushing oil pump had tripped and the set ran out of fuel and starting air.

It was not possible for the Cruachan operators to determine that a 33 kV. supply at reduced voltage was being given at Taynuilt from the 132 kV. system as the indicating instrument in the Control Room has a false zero at 20 kV. and there was no adequate speech with Port-na-Craig or Kirkintilloch. The operators assumed that no supply was available at Taynuilt and opened all the feeders.

Cruachan were contacted at 03.40 hrs. on the G.P.O. telephone and informed that the Windyhill/Dalmally 275 kV. lines were still live at Dalmally. Arrangements were made to defeat the Main Transformer cooling water and oil flow trips and at 04.08 hrs. L25 was closed at Dalmally energising T2. Cruachan Sets 4 and 2 were synchronised and brought up to full load at 04.15 hrs. and 04.57 hrs. respectively. Carrier communication was re-established between Port-na-Craig and Cruachan at 04.15 hrs. The voltage at Windyhill at this time was about 290 kV.

Set 2 was taken out of service from 05.19 - 05.58 hrs. for repairs to the field switch contacts.

2.4 H.E.B./S.S.E.B. Transfer

In Appendix 5 are copies of charts showing:-

(a) MW. transfer at Abernethy, Bonnybridge, Windyhill, Strathleven and Kincardine - Tealing N1 and S2. The chart for Kincardine S2 is reversed and incorrect in magnitude.

(b) MVAr transfer at Abernethy, Windyhill and Kincardine - Tealing N1 and S2.

(c) MW. transfer on Windyhill - Dalmally 275 kV. lines.

2.5 System Voltages

In Appendix 6 are copies of charts showing:-

(a) 132 kV. busbar voltage at Beauly.

(b) 132 kV. busbar voltage at Errochty.

3. Damage to Plant

3.1 Thermal Plant

At Carolina Port 'B' nine auxiliary A.C. contactors were burnt out.

3.2 Hydro Plant

At Pitlochry Set 2 the main lead from the field switch to rotor slip ring fused. The field discharge resistance and pyrotenex cabling in the field switch cubicle were also damaged.

3.3 Pumped Storage Plant

The contacts on the field switch at Cruachan Set 2 were damaged.

3.4 Transmission Plant

Both grid transformers at Lunanhead had suspected failure of insulation between core and earth. Subsequent investigation showed that one transformer was sound and that the core bolt insulation on the second transformer had failed.

3.5 Distribution Plant

A number of transformer tap changers stuck but no major damage has been reported.

3.6 Consumers Equipment

In the Peterhead Area a number of domestic off-peak heater elements and the Decca radar equipment were damaged. A number of industrial motors were damaged in the Dundee Area.

Appendix 1

H.E.B. Generating Plant on Load Prior to Fault

Group	Station		Capacity MW. s.o.	Load MW. s.o.	Group Total MW. s.o.
Tummel	Cuaich		2.4	2	
	Ericht		2.2	2	
	Rannoch	Set 1	14	14	
		Set 2	14	14	
	Gaur		6	6	
	Tummel	Set 1	18	17	
		Set 2	18	17	
	Clunie	Set 1	20.4	20	
		Set 3	20.4	19	
	Pitlochry	Set 1	7.5	7.5	
		Set 2	7.5	7.5	126
Breadalbane	Cashlie		11	6	
	Lucreoch		4	4	
	Lochay	Set 1	22.5	21.5	
		Set 2	22.5	21.5	
	Dalchonzie		4	4	57
Sloy	Lairige		6	6	
	Striven	Set 1	3	3	
		Set 2	3	3	
	Loch Gair		6	6	18
Awe	Inverawe		29	29	
	Kilmelfort		2	2	31
Conon	Mossford	Set 1	12	12	
		Set 2	12	12	
	Achanalt		2	2	
	Luichart	Set 1	12	13	
		Set 2	12	13	
	Orrin		18	18	
	Torr Achilty	Set 1	7.5	5	
		Set 2	7.5	5	80
Beauly	Mullardoch		2	2	
	Fasnakyle	Set 1	22	21	
		Set 2	22	21	
		Set 3	22	21	
	Deanie	Set 1	19	19	
	Culligran	Set 1	2	2	
	Aigas	Set 1	10	9	
		Set 2	10	9	
	Kilmorack	Set 1	10	8	
		Set 2	10	8	120
Garry Moriston	Quioch		22	22	
	Invergarry		20	18	
	Loyne		0.5	0.5	
	Ceannancroc	Set 1	16	16	
		Set 2	4	4	
	Glenmoriston	Set 1	18	18	
		Set 2	18	18	
	Foyers		5	5	102
Shin	Cassley		10	10	
	Lairg		4	3	
	Shin	Set 1	12	12.5	
		Set 2	12	12.5	38
Small Stations	-		7	7	7
Hydro Total			603.9	579	579

Thermal/

Group	Station	Capacity MW. s.o.	Load MW. s.o.	Group Total MW. s.o.
Hydro Total		603.9	579	579
Thermal	Carolina Port 'B' U1 U2	115 115	57 47	104
Grand Total		833.9	683	683

Incidence of Loss of H.E.B. Generation Capacity

Set		Time Tripped	MW.	Cum. MW.	Protection Indications
Dalchonzie		03.06	4	4	Thermal overload
Lairige		03.06	6	10	Negative phase sequence
Loch Gair		03.06	6	16	Negative phase sequence
Kilmelfort		03.10	2	18	Overcurrent. Blue phase, under frequency.
Inverawe		03.12	29	47	Overcurrent. Red phase, overspeed, intertrip.
Lubreoch		03.13	4	51	Thermal overload. Overspeed.
Carolina Port 'B'	Set 1	03.15)	230	281	Negative phase sequence
	Set 2	03.15)			
Lochay	Set 1	03.15)	45	326	Line LL tripped. (O/c Red phase). Both machines overvoltage.
	Set 2	03.15)			
Kerry Falls	Set 1	03.15	.5	326.5	Overcurrent
	Set 2	03.15	.5	327	Overcurrent
Striven	Set 1	03.15	3	330	Overcurrent. Red phase.
	Set 2	03.15	3	333	Overcurrent. Red phase.
Clunie	Set 1	03.17	20.4	353.4	Overcurrent. Red and Blue.
	Set 3	03.17	20.4	373.8	Overcurrent. Blue.
Pitlochry	Set 1	03.17	7.5	381.3	Overcurrent. Red and Blue.
	Set 2	03.17	7.5	388.8	Overcurrent. Red and Yellow.
Rannoch	Set 1	03.20	14	402.8	Overvoltage and o/c)
	Set 2	03.20	14	416.8	Overvoltage and o/c)
Gaur		03.20	6	422.8	Overcurrent. 3 phases)
Ericht		03.20	2.2	425	Thermal protection. Overspeed.) See note
Cuaich		03.20	2.4	427.4	Overvoltage.
Quoich		03.20	22	449.4	Overvoltage/N.P.S.
Invergarry		03.20	20	469.4	Overcurrent/N.P.S.
Loyne		03.20	0.5	469.9	Undervoltage
Ceannacroc	Set 1	03.20	16	485.9	Overcurrent/N.P.S.
	Set 2	03.20	4	489.9	Overcurrent/N.P.S.
Culligran	Set 1	03.25	2	491.9	Overspeed
Lussa	Set 2	03.25	1.2	493.1	Overcurrent
Fasnakyle	Set 1	03.40	22	515.1	Governor drive failure.

Note: At Tummel Bridge the negative phase sequence protection operated and the switches on Errochty/Tummel/Rannoch North and South lines opened on intertrip.

Plant Remaining on Load During Fault on System/

Plant Remaining on Load During Fault on System

Tummel Sets 1 and 2
Cashlie
Mossford Sets 1 and 2
Achanalt
Luichart Sets 1 and 2
Orrin
Torr Achilty Sets 1 and 2
Mullardoch
Fasnakyle Sets 2 and 3
Deanie Set 1
Aigas Sets 1 and 2
Kilmorack Sets 1 and 2
Glenmoriston Sets 1 and 2
Foyers
Cassley
Lairg
Shin Sets 1 and 2
Small Stations (5 MW.)

Total Capacity of 319 MW. sent out.

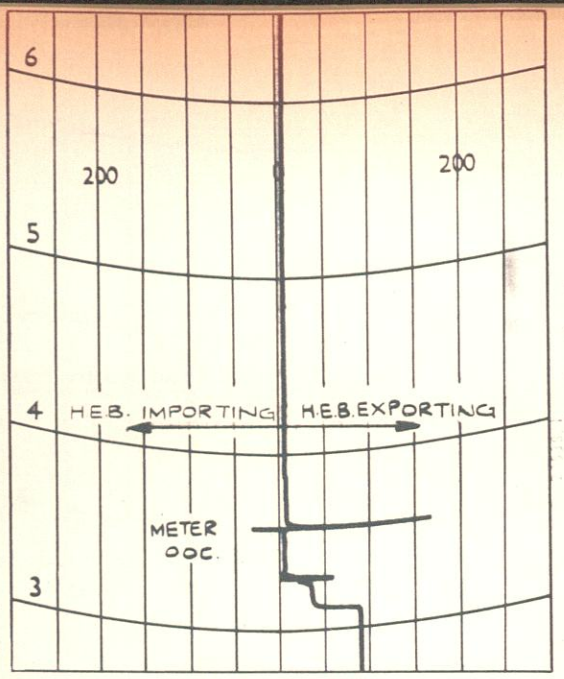
Sequence of Synchronising of H.E.B. Generating Plant

Set	Time tripped (hrs.)	Time Synch. To System Hrs.	Time Synch. To System MW.	Cumulative Total MW.
Lochay 1	03.15	03.25	22	22
Finlarig	-	03.30	30	52
Errochty 1	-	03.40	25	77
Sloy 3	-	03.40	33	110
Sloy 4	-	03.45	32	142
Errochty 3	-	03.45	25	167
Quoich	03.20	03.50	22	189
Lochay 2	03.15	03.55	23	212
Culligran 2	-	03.58	22	234
Fasnakyle 1	03.40	04.00	22	256
Errochty 2	-	04.00	25	281
Lubreoch	03.13	04.00	4	285
Kerry Falls	03.15	04.00	1	286
Invergarry	03.20	04.05	20	306
Ceannacroc	03.20	04.10	20	326
Clachan	-	04.12	40	366
Loch Gair	03.06	04.14	6	372
Cruachan 4	03.10	04.15	100	472
Striven	03.15	04.16	6	478
Rannoch and Tummel*	03.20	04.28	76	554
Kilmelfort	03.10	04.30	2	556
Culligran 1	03.25	04.35	2	558
Lussa	03.25	04.45	2	560
Inverawe	03.12	04.45	29	589
Cruachan 2	03.10	04.52	100	689
Clunie 1	03.17	04.55	20	709
Grudie Bridge 2	-	04.55	12	721
St. Fillans	-	04.57	21	742
Dalchonzie	03.06	05.00	4	746
Clunie 2	-	05.06	20	766
Carolina Port 'B' 1	03.15	05.15	115	881
Allt-na-Lairige	03.06	05.30	6	887
Pitlochry 1	03.17	05.30	7.5	894
Carolina Port 'B' 2	03.15	08.53	112	

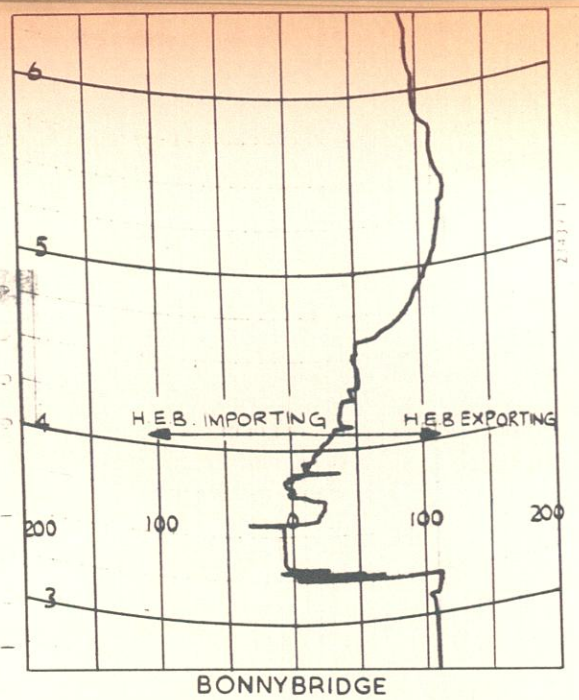
* On isolated load from 03.31 hrs.

Transmission Circuit Breaker Operations

Switch		Circuit	Time (hrs.) Tripped	Time (hrs.) Reclosed
Charleston	605	CAS	03.07	03.12
Abernethy	2TO	T2	03.11	04.10
Dalmally	L15, S10	YCS	03.11	04.40
Dalmally	L25	YCN	03.11	04.08
Charleston	605	CAS	03.13	03.14
Killin	305	LL	03.15	03.20
Errochty	905	ETN/TRN	03.20	03.28
Errochty	1005	ETS/TRS	03.20	03.28
Tummel	1TO	T1	03.20	03.29
Rannoch	2TO	T2	03.20	03.55
Errochty	905	ETN/TRN	03.29	03.35
Errochty	1005	ETS/TRS	03.29	03.35
Tummel	1TO	T1	03.29	04.26
Tummel	2TO	T2	03.29	04.28



ABERNETHY



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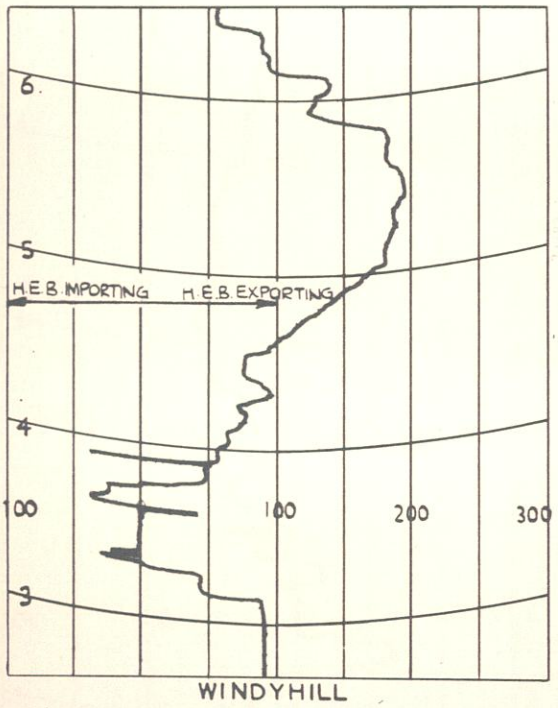

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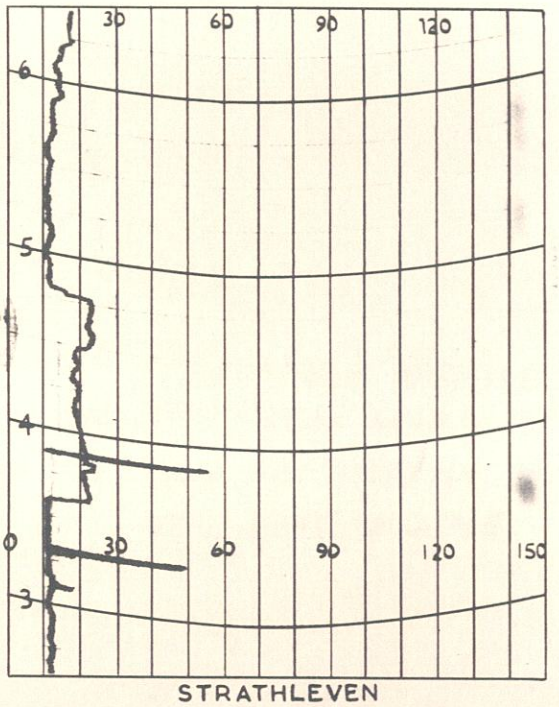

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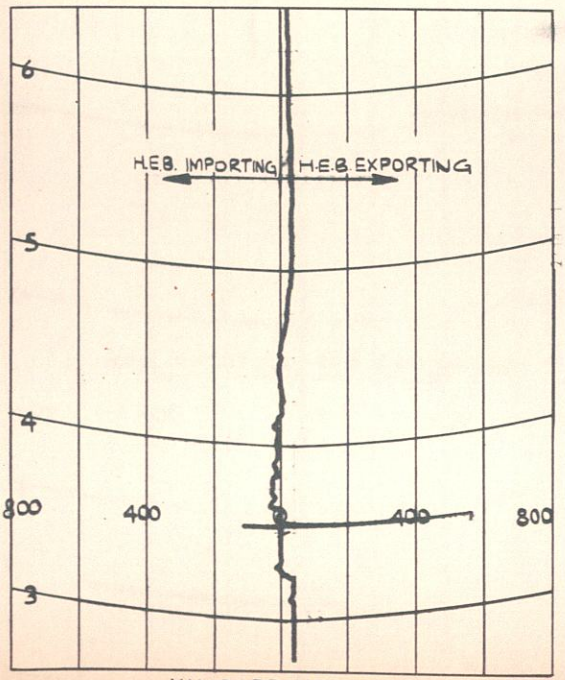
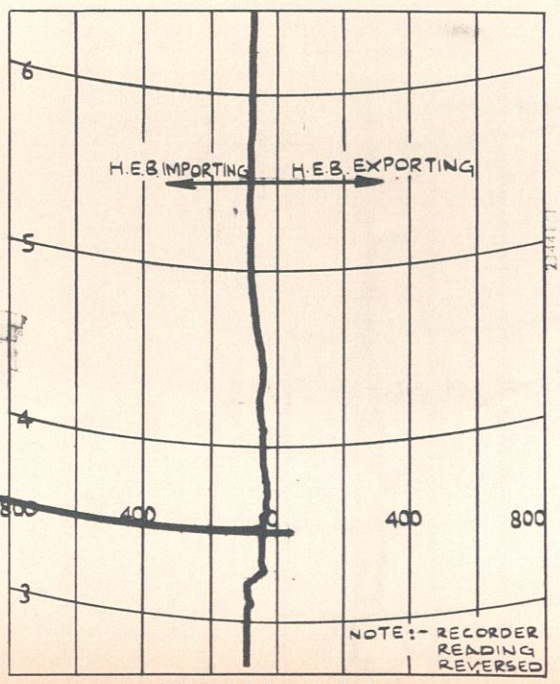


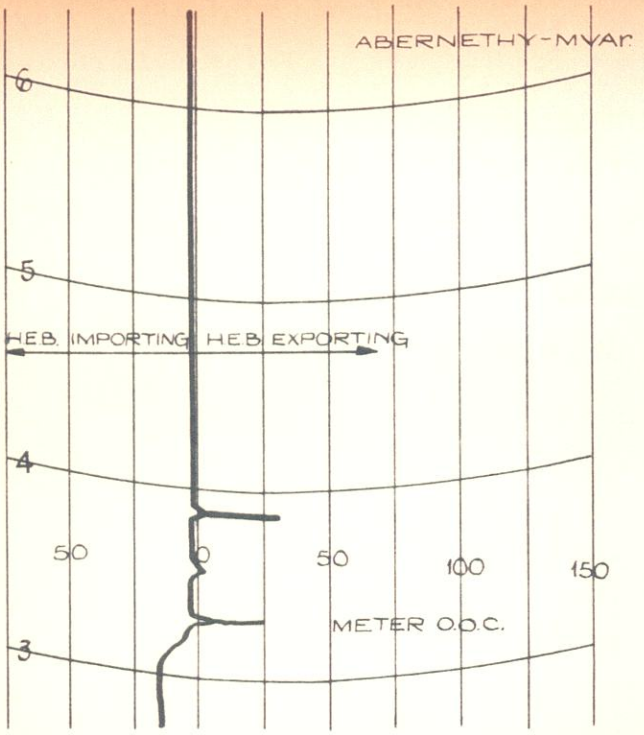
KINCARDINE N.1

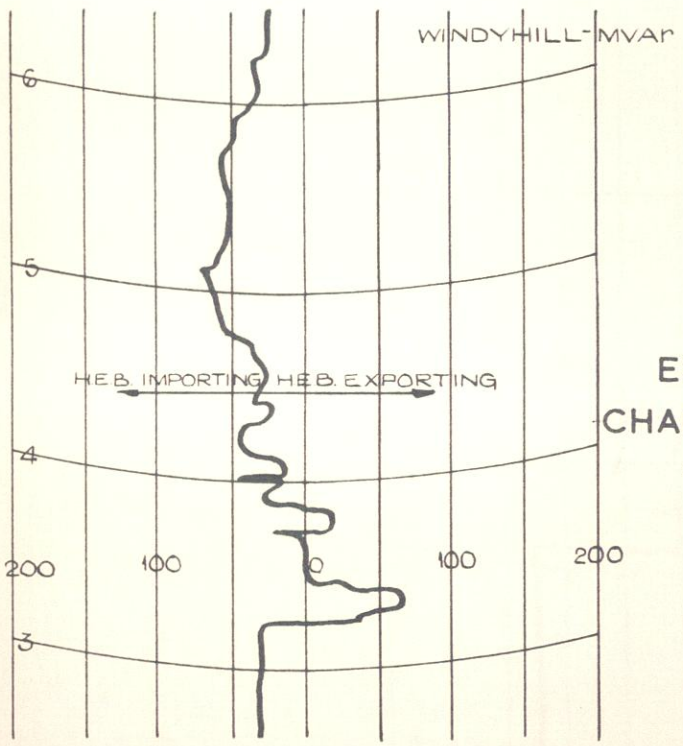


KINCARDINE S.2

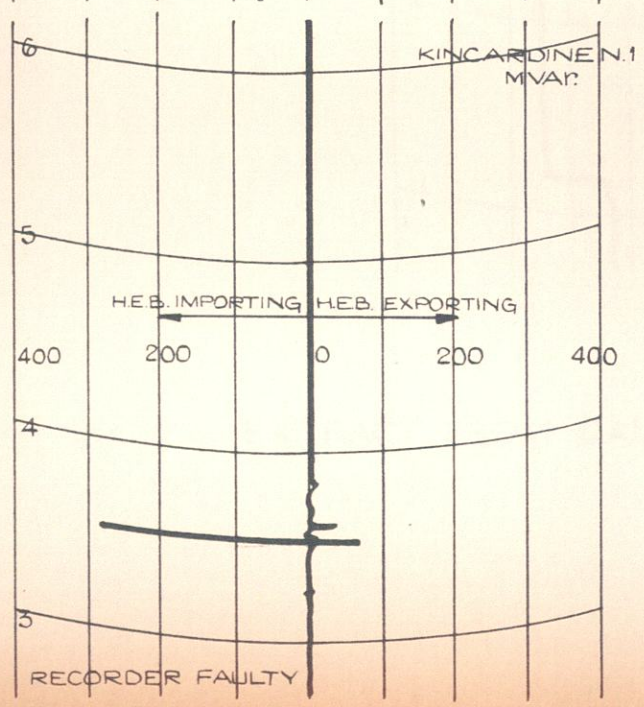
APPENDIX 5(a)(H.E.B.)
H.E.B./ S.S.E.B. MW. TRANSFER.

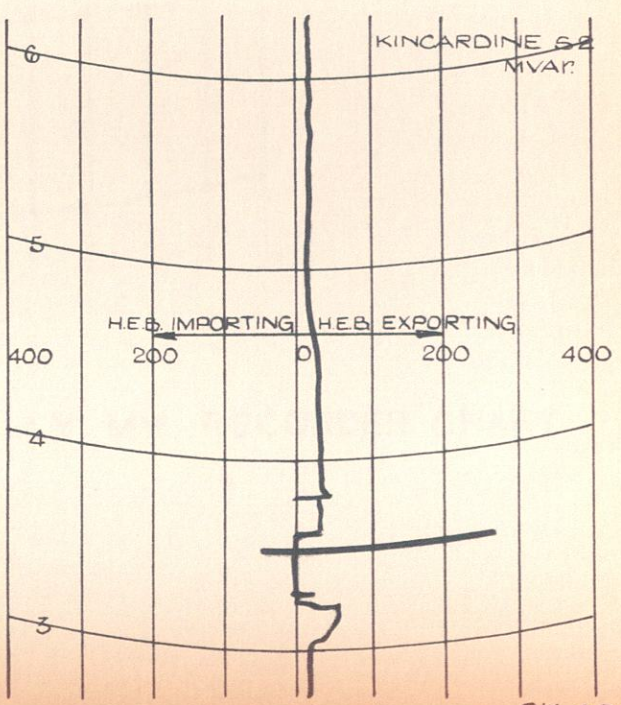
SK 4080





APPENDIX 5(b)(H.E.B.)
EXTRACTS FROM MVAr RECORDER CHARTS FOR ABERNETHY. WINDYHILL. AND KINCARDINE.





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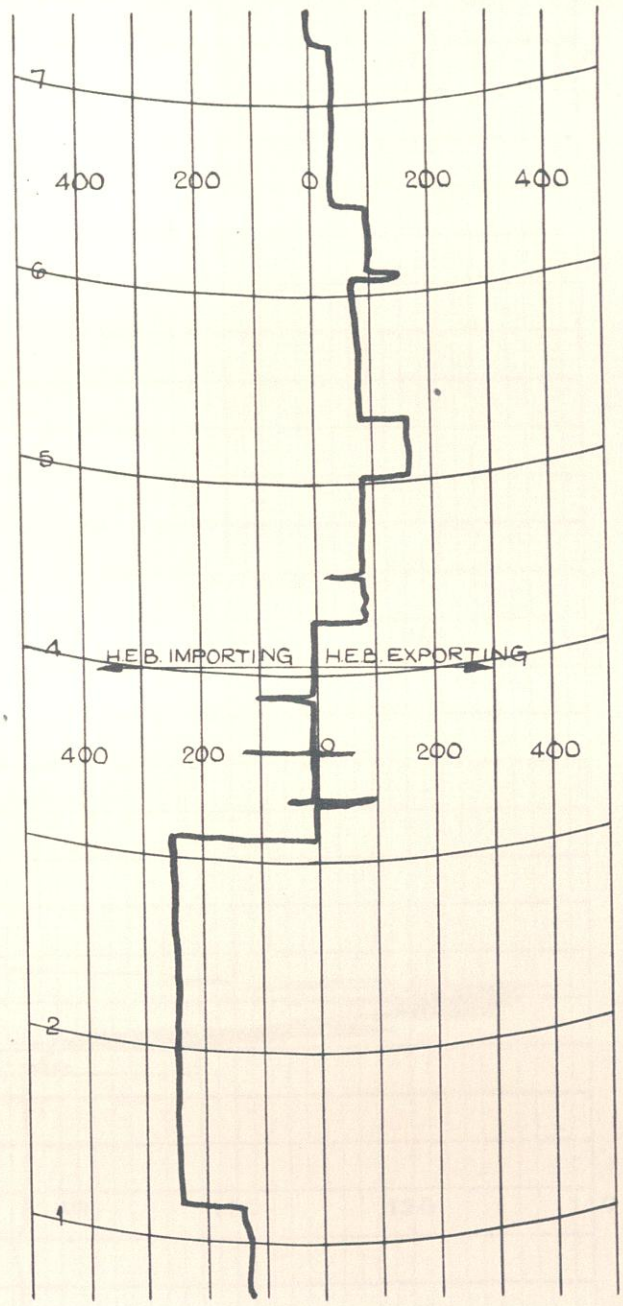
APPENDIX 5(c)(H.E.B.)

MW TRANSFER DALMALLY - WINDY HILL



EXTRACT FROM DALMALLY MW RECORDER CHART

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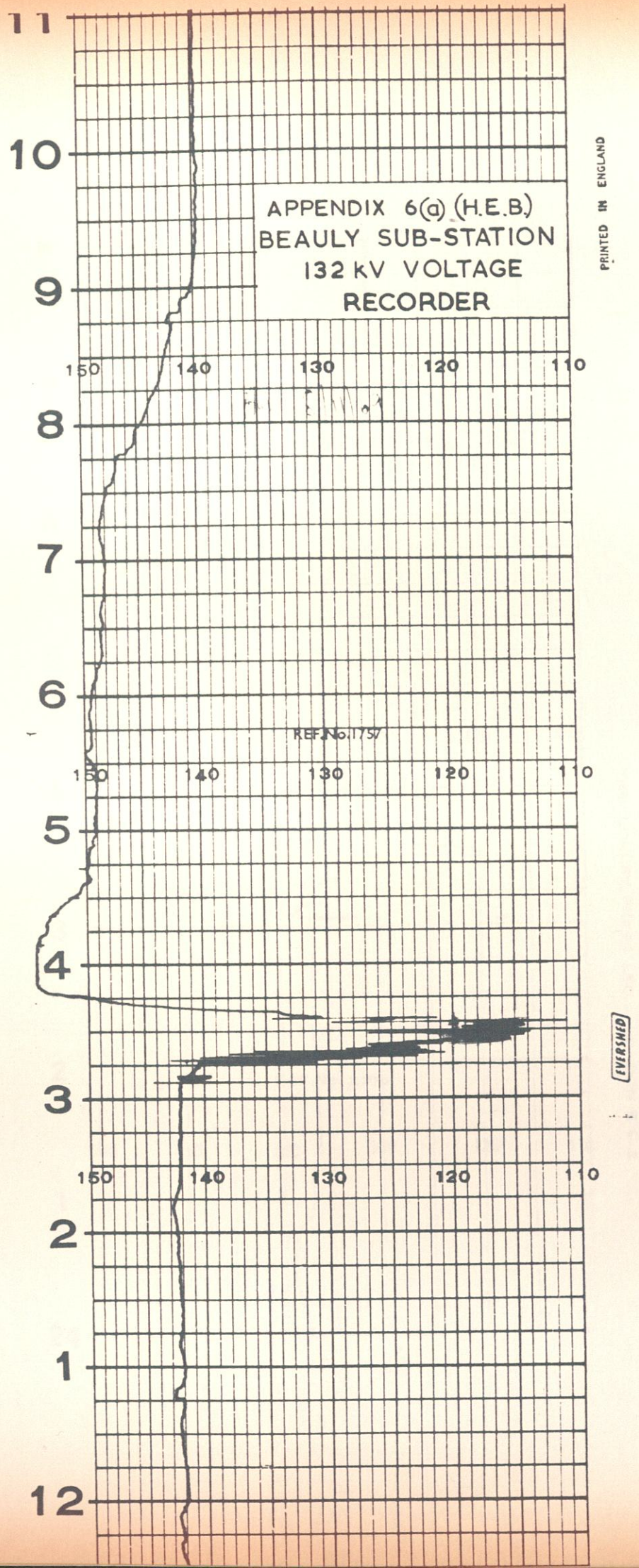
APPENDIX 6(a) (H.E.B.)
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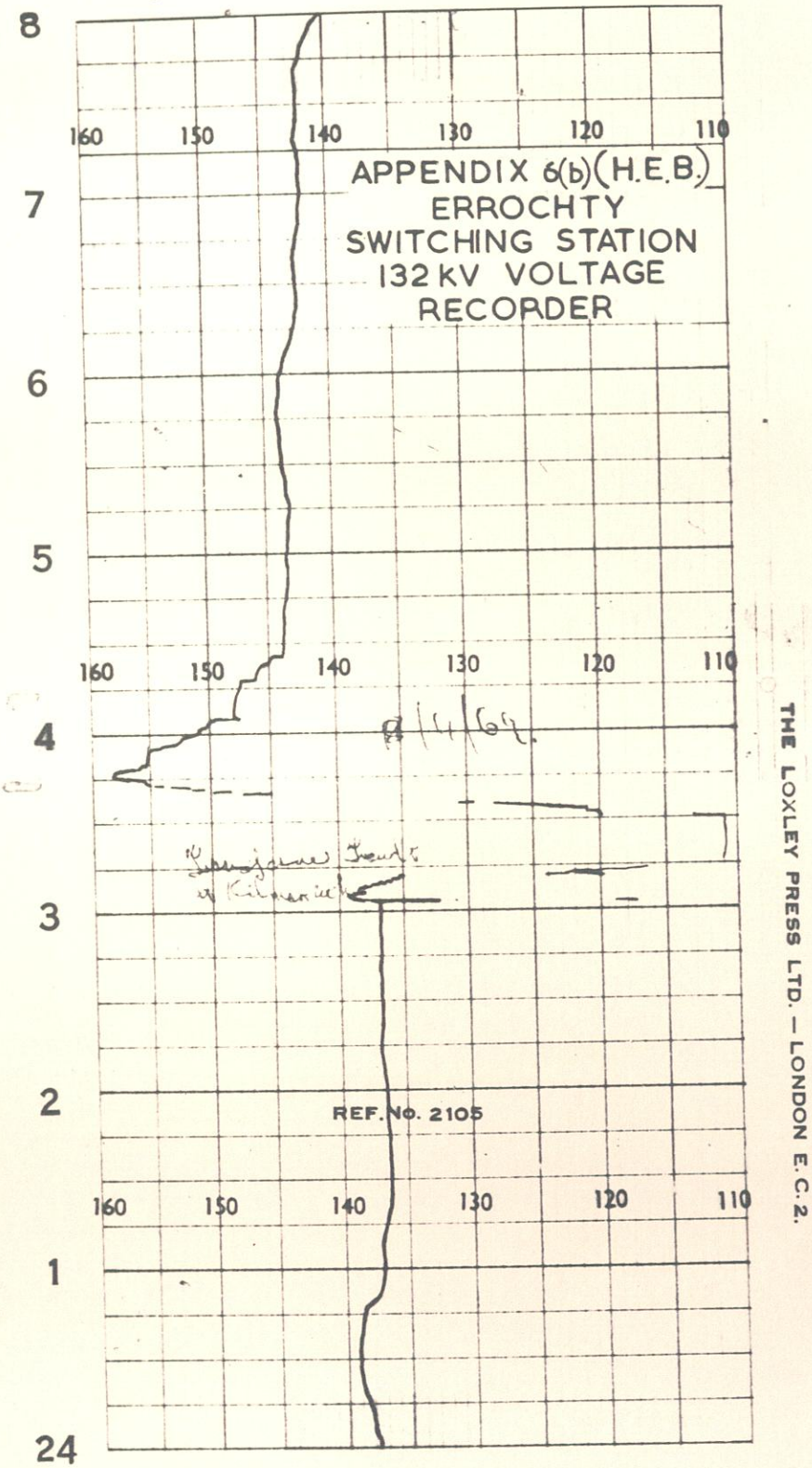
APPENDIX 6(b)(H.E.B.)
ERROCHTY
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132 kV VOLTAGE
RECORDER
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APPENDIX VI

CENTRAL ELECTRICITY GENERATING BOARD
NORTH EASTERN REGION
PLANNING DEPARTMENT SYSTEM OPERATION BRANCH

OPERATIONAL REPORT ON MAJOR DISTURBANCE ON THE CENTRAL ELECTRICITY GENERATING BOARD SYSTEM AT 03.06 HOURS ON SATURDAY 8 NOVEMBER 1969

1. Summary

This report details the effect on the Central Electricity Generating Board System of an uncleared fault on the South of Scotland Electricity Board Strathaven - Kilmarnock - Ayr No. 1 275/33 kV. Transformer Feeder. The fault occurred at 03.06 hrs. and was sustained until 03.34 hrs. As a result of the fault there was a loss of 540 MW. of generation at Blyth 'A' and 'B' Power Stations, and a reduction of 15 MW. of generation at The United Kingdom Atomic Energy Authority Power Station at Calder Hall, and an emergency load reduction of 176 MW. of consumers demand in the North Eastern Electricity Board Area.

The fault is the subject of a Board of Inquiry by the South of Scotland Electricity Board.

2. Prior to the Fault

Diagram 1 depicts the system running arrangements in the Northern Section of the Central Electricity Generating Board System prior to the fault, and Appendix 1 details the operational conditions on that section of the system.

3. Disturbance during the Fault

Immediately following the initiation of the fault there was a rise in system frequency followed by a fall to 49.7 Hz over a period of approx. 15 minutes. The frequency then rose to 50 Hz and, on clearance of the fault, fell rapidly to 49.53 Hz, rising again to 50.1 Hz over a period of 20 minutes.

During the period in which the fault was sustained the following voltage depressions and phase unbalance was experienced in the Northern Section of the Central Electricity Generating Board System:-

(a) Maximum Voltage Depression Experienced

Blyth 275 kV. Substation	200 kV.
Spennymoor 132 kV. Substation	110 kV.
Windscale 132 kV. Substation	118 kV.
Harker 275 kV. Substation	160 kV.
Harker 132 kV. Substation	102 kV.
Monk Fryston 275 kV. Substation	255 kV.
Bradford West 275 kV. Substation	265 kV.

Sustained voltage depression as low as 30% was experienced on the North/

North Eastern Electricity Board Distribution System supplied from the North Eastern Section of the Central Electricity Generating Board Primary System.

(b) Fault Currents

Approximately 1,000 MVArs was fed into the fault from the Central Electricity Generating Board System, the distribution being as follows:-

Harker - Strathaven 1 275 kV. Overhead line	450 MVArs to Strathaven
Stella West - Cockenzie 1 275 kV. Overhead line	280 MVArs to Cockenzie
Stella West - Cockenzie 2 275 kV. Overhead line	280 MVArs to Cockenzie

During the disturbance the following phase unbalance was reported on Central Electricity Generating Board circuits:-

Blyth - Tynemouth 275 kV. Overhead line	red phase 140 amps yellow phase 140 amps blue phase 70 amps
Blyth 'B' Power Station No. 6 Machine	red phase 1800 amps yellow phase 2100 amps blue phase 1000 amps

Phase unbalance was also reported on all circuits at Stella West and Harker Substations.

The low voltage and unbalanced fault current caused the following loss of generating plant at Blyth 'A' and 'B' Power Stations:-

03.18	Generator B5 taken off load by hand.
03.20	Generator A4 tripped on back-up protection. (Negative Phase Sequence)
03.25	Generator A2 taken off load by hand.
03.26	Generator B6 taken off load by hand.

Appendix 2 details the effect upon individual machines in the Northern Section of the Central Electricity Generating Board System during the fault.

The effect of this loss of generation was partially off-set during the fault by reduced consumers demand due to low voltage in the South of Scotland Electricity Board and the Northern Section of the Central Electricity Generating Board System.

In anticipation of a voltage rise following the fault clearance, shunt reactors were switched into service in the Yorkshire Section of the Central Electricity Generating Board System, and Generating Stations in the Northern Section were alerted to the possibility of a sudden voltage rise.

4. Disturbance following Fault Clearance/

4. Disturbance following Fault Clearance

When it was realised that it was impossible to remotely operate the switchgear at Strathaven 275 kV. Substation, switching instructions were given at 03.29 hrs. by the South of Scotland Electricity Board Grid Control Engineer to make the section of busbars dead by opening at the remote end those circuits selected to the busbar at Strathaven. As a result of this switching and the clearance of the fault, there was a rapid rise in voltage and the following voltage levels were reported:-

Blyth 275 kV. Substation	282 kV.
Spennymoor 132 kV. Substation	144 kV.
Windscale 132 kV. Substation	143 kV.

This rapid rise in voltage caused restoration of the consumers demand both in the South of Scotland Electricity Board and the Northern Section of the Central Electricity Generating Board System and, coupled with the loss of generating plant that had been sustained throughout the fault, resulted in heavy power flows across the Northern Section of the Central Electricity Generating Board System of the South of Scotland Electricity Board. The overall deficit of generating plant caused the system frequency to fall rapidly to 49.53 Hz. As the South of Scotland Electricity Board system was connected to the Central Electricity Generating Board System via the Stella West - Cockenzie 1 and 2 circuits only these power flows resulted in the following overloading of primary circuits in the Northern Section of the Central Electricity Generating Board System:-

	Before Fault	After Fault
Stella West - Cockenzie 1 & 2	Float	740 MW. from Stella West-Cockenzie
Blyth - Harker 1 & 2	100 MW. from Blyth - Harker	300 MW. from Harker - Blyth
Norton - Osbaldwick - Monk Fryston 1 & 2	440 MW. from Osbaldwick/ Monk Fryston to Norton	1320 MW. from Osbaldwick/ Monk Fryston to Norton

As the cold weather 10 minute rating of the Norton - Osbaldwick - Monk Fryston 1 and 2 circuits is 620 MW. each, the Leeds Area Grid Control Engineer instructed the emergency shedding of 150 MW. of consumers demand to reduce the loading of these circuits to within acceptable limits. Appendix 3 details the shedding and times at which this was carried out. This action also contributed to the recovery of system frequency.

The rapid rise in voltage following the fault clearance caused difficulty on the North Eastern Electricity Board Distribution System, as automatic tap changing equipment had operated to correct the low voltage, with the result that there was a pronounced high voltage when the fault was cleared. In a number of cases the continuous succession of tap operations caused the tap changer motor thermal overload protection to operate and prevented further tap changing, with the result that excess voltage was experienced until the thermal overload relays had been re-set. In other cases the tap changers got out of step and locked out with similar effect on the voltage. Over voltages of as high as 16% were experienced on the Distribution System.

DETAILS OF OPERATING CONDITIONS ON THE NORTHERN SECTION OF THE C.E.G.B. SYSTEM PRIOR TO THE FAULT

(a) Voltage Levels at Individual Points on the System

Blyth 275 kV. Substation	272 kV.
Spennymoor 132 kV. Substation	140 kV.
Windscale 132 kV. Substation	138 kV.
Monk Fryston 275 kV. Substation	274 kV.
Bradford West 275 kV. Substation	278 kV.

(b) Generation and Consumers Demand

	Generation MW. s.o.	Consumers Demand MW.
Blyth A2	112	
A3	90	
A4	114	
Blyth B5	124	
B6	180	
North Tees C2	30	
Sub-Total	650	990
Calder Hall U.K.A.E.A.	236	
Sub-Total	236	250

(c) Transfer Between S.S.E.B. and C.E.G.B. Systems

Stella West - Cockenzie 1	275 kV. Overhead Line	Float
Stella West - Cockenzie 2	275 kV. Overhead Line	Float
Harker - Strathaven 1	275 kV. Overhead Line	60 MW. from C.E.G.B. to S.S.E.B.
Harker - Chapelcross	132 kV. Overhead Line	70 MW. from S.S.E.B. to C.E.G.B.
	Net Transfer MW.	10 MW. from S.S.E.B. to C.E.G.B.
	Net Transfer MVArs	50 MVArs from C.E.G.B. to S.S.E.B.

DETAILS OF EFFECT OF FAULT UPON INDIVIDUAL MACHINES IN THE NORTHERN SECTION OF THE C.E.G.B. SYSTEM

Blyth 'A' & 'B' Power Stations

Generator A4

At 03.08 hours the machine negative phase sequence alarm operated and would not re-set.

The output of the machine was progressively reduced to assist the auxiliary position which had been affected by the low voltage and had been reduced to 60 MW. when the machine tripped on negative phase sequence at 03.20 hours.

Generator A2

At 03.12 hours difficulty was experienced due to auxiliary plant tripping when the following auxiliaries were lost:-

Alternator Cooling Pump

Extraction Pump

Generator Step-up Transformer cooler circulating water pump

Standby auxiliary plant was started and the machine output was reduced to assist the auxiliary position.

The 2B feed pump which was supplied from the Station Transformer tripped, and as the 2A feed pump was out of service for maintenance the machine was shut down in a normal manner at 03.25 hours.

Generator B5

At 03.10 hours the negative phase sequence alarm operated and would not re-set, the machine having an out of balance of 1000 Amps between the blue and the other two phases.

The machine output was reduced to 60 MW. where the following alternator phase currents were recorded:-

red phase	1800 amps
yellow phase	2100 amps
blue phase	1000 amps

As the negative phase sequence alarm had not cleared the machine was shut down by hand at 03.18 hours. The Shift Charge Engineer, in the absence of any other information, thought that No. 5 Generator was causing the unbalanced loading. Being aware of the concern for English Electric machine rotor cracking he decided to shut down the machine.

Generator B6

At 03.15 hours, following the successive tripping of machine auxiliaries, the output was reduced to 130 MW. The negative phase sequence alarm and the rotor earth fault alarm operated.

The/

The 6B booster feed pump tripped and feed supply was lost to the boiler. Boiler firing was then tripped and the output of the machine reduced to zero. At zero load the machine was supplying 150 MVArs with the following alternator currents:-

red phase	2000 amps
yellow phase	6000 amps
blue phase	Off scale (meter scaling 12000 amps)

In order to safeguard the machine the Charge Engineer decided to disconnect it from the system leaving it to supply its own auxiliaries, so that when the boiler firing was resumed the machine would be in a position to synchronise with the system.

However, following disconnection the machine A.V.R. developed trouble and caused low voltage on Unit Board resulting in operation of under voltage protection and shut down of all auxiliaries. The machine then had to be shut down.

The negative phase sequence relays at Blyth are as follows:-

'A' Station - C.T. Ratio 6000/5 Alarm 10% $I_2^2 t = 7$

'B' Station - C.T. Ratio 12000/5 Alarm 10% $I_2^2 t = 7$

In October of last year the Station had been informed by English Electric that there had been cracking of the electrical rotor on machines similar to those in the 'B' Station, due to negative phase sequence currents. The setting of the negative phase sequence relay would require an $I_2^2 t = 2$ setting which cannot be achieved on present relays. New relays have been ordered and delivery is awaited. Operating staff have been instructed to prevent long term out-of-balance running until new negative phase sequence relays are fitted.

Calder Hall Power Station, U.K.A.E.A.

At the U.K.A.E.A. Power Station at Calder Hall the disturbance was first observed as a fall in voltage from 11.8 to 11.2 kV. which recovered immediately and remained stable for about 2 minutes. There was then surging on all machines of the order of 2/3 MW. per set with substantial surging on the Calder Hall - Roosecote line which swung between 0 and 100 MW. There were also smaller swings on the other 132 kV. lines at Calder Hall.

In order to improve the ability of the plant at Calder Hall to withstand disturbance, the speed of the reactor gas circulators was reduced, thereby reducing output by 15 MW. (The reduction of gas circulator speeds is based on results of shedding studies which indicate that at high blower speed the reactors are liable to be tripped by disturbance on the electrical system).

C.E.G.B. System (Southern Section)

Generating plant on this section of the system was not affected by the disturbance.

Restoration of Generating Plant/

Restoration of Generating Plant

Generating plant at Blyth 'A' & 'B' Power Stations was returned to service as follows:-

04.05 hours	Generator B5 on load.
07.14 hours	Generator A4 on load.
08.47 hours	Generator A2 on load.
16.32 hours	Generator B6 on load (delayed due to a shortage of make-up water).

Generator B8 which had been out of service at the time of the fault, due to an outage, was returned to service at 06.15 hours.

Instructions were given by the Leeds Area Grid Control Engineer at 03.16 hours to bring additional generating plant capacity on the system in the Northern Section of the Central Electricity Generating Board System, and despite initial difficulties due to low voltage (03.06 hours to 03.34 hours) plant was brought on load as follows:-

04.16 hours	Stella North Generator 3	on load
04.20 hours	North Tees 'C' Generator 1	on load
04.33 hours	Stella North Generator 2	on load
04.40 hours	Stella South Generator 3	on load
04.41 hours	Dunston Generator 5	on load
04.42 hours	Stella North Generator 4	on load
04.53 hours	Dunston Generator 6	on load.

DETAILS OF EMERGENCY SHEDDING CARRIED OUT IN THE NORTHERN SECTION OF THE C.E.G.B. SYSTEM IN ORDER TO RELIEVE LINE OVERLOADINGS

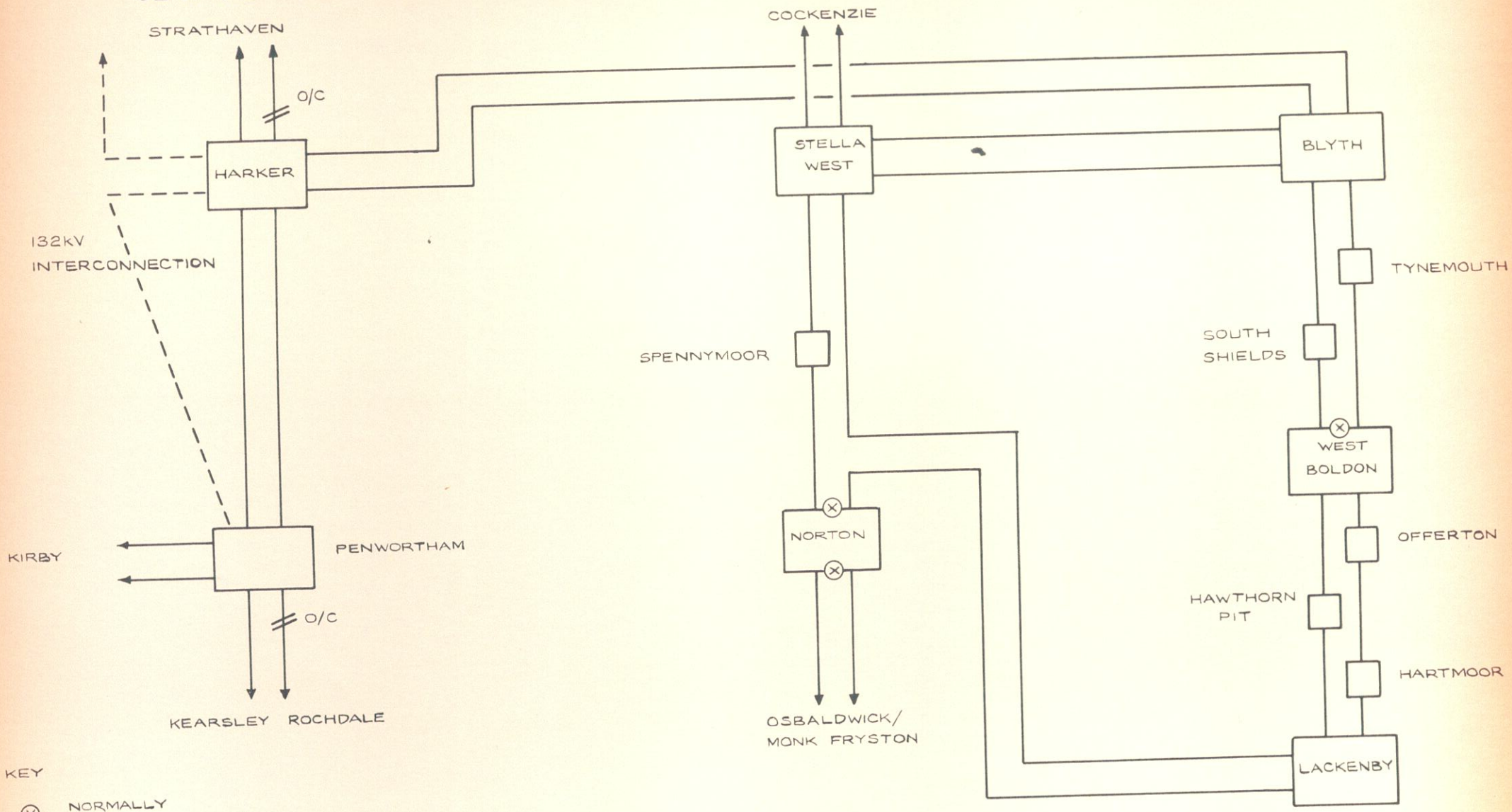
Dunston	15 MW.	from 03.30 hours until 04.38 hours
Coalburns	14 MW.	from 03.34 hours until 04.50 hours
Blyth	79 MW.	from 03.35 hours restored between 04.54 and 05.40 hours.
High Flatts	2 MW.	from 03.35 hours until 04.46 hours
Chirton Grange)	22 MW.	from 03.38 hours until 04.48 hours
Flatworth)		03.34 hours until 04.46 hours
Hart Moor	4 MW.	from 03.40 hours until 04.59 hours
Hart Moor (Hartlepool Steel)	15 MW.	from 03.25 hours until 04.46 hours
Hawthorn Pit	5 MW.	from 03.41 hours until 04.45 hours
Spennymoor	10 MW.	from 03.43 hours until 04.44 hours
North Tees	10 MW.	from 03.56 hours until 04.48 hours
Total Disconnected	176 MW.	

Appendix 3

DETAILS OF EMERGENCY SHEDDING CARRIED OUT IN THE NORTHERN SECTION OF THE C.E.G.B. SYSTEM IN ORDER TO RELIEVE LINE OVERLOADINGS

Dunston	15 MW.	from 03.30 hours until 04.38 hours
Coalburns	14 MW.	from 03.34 hours until 04.50 hours
Blyth	79 MW.	from 03.35 hours restored between 04.54 and 05.40 hours.
High Flatts	2 MW.	from 03.35 hours until 04.46 hours
Chirton Grange)	22 MW.	from 03.38 hours until 04.48 hours
Flatworth)		03.34 hours until 04.46 hours
Hart Moor	4 MW.	from 03.40 hours until 04.59 hours
Hart Moor (Hartlepool Steel)	15 MW.	from 03.25 hours until 04.46 hours
Hawthorn Pit	5 MW.	from 03.41 hours until 04.45 hours
Spennymoor	10 MW.	from 03.43 hours until 04.44 hours
North Tees	10 MW.	from 03.56 hours until 04.48 hours
Total Disconnected	176 MW.	

CENTRAL ELECTRICITY GENERATING BOARD NORTH EASTERN REGION



KEY

⊗ NORMALLY OPEN

—— 275kV.

--- 132kV.

O/C OUT OF COMMISSION

NORTHERN SECTION OF C.E.G.B. MAIN PRIMARY SYSTEM.

SK. 4070

DIAGRAM 1

275 kV. System Fault - November 8th, 1969

Report on the Operation of the Protection

Introduction

This report deals with the protection aspects of the faults which occurred on the Strathaven-Kilmarnock-Ayr feeder on 8th November, 1969, when, due to a defective tripping relay on the No. 1 feeder, the feeder failed to clear. The notes cover the behaviour of the protection during the incident, the actions which have already been taken, and the short term and long term actions which are still required.

The sequence of events and corroboration obtained from charts is shown on the schedule attached to this report.

Protective Gear Operations

During the course of the fault, the following protective gear operations took place.

At Strathaven

Kilmarnock 1	Distance Protection Zones 1 & 2	R-Y R-N	Y-B Y-N	B-R B-N
	Overcurrent	R	Y	B
	Intertrip Receive			
Kilmarnock 2	Distance Protection Zones 1 & 2		Y-B Y-N	B-N
	Intertrip Receive			
	Trip Relay			
Wishaw	Overcurrent			B
	Trip Relay			
Bus Coupler	Overcurrent			B
	Trip Relay			

At Wishaw

Strathaven 2/SGT3	Line Trip Relay
	SGT3 H.V. Trip Relay
	L.V. Trip Relay

At Kilmarnock

SGT1	Main Buchholz Surge	
	Winding Temperature	
	Intertrip Send	
SGT2	Directional Overcurrent	R
	'A' Trip Relay (33 kV.)	
	'B' Trip Relay (33 kV.)	

At Ayr/

At Ayr

SGT1	Trip Relay	
	Intertrip Receive	
SGT2	Directional Overcurrent	R
	Trip Relay	

Sequence of Circuit Breaker Operations

The sequence of circuit breaker operations, both manual and automatic, which ultimately led to the clearance of the fault, is detailed in the schedule of sequence of events.

Analysis of Protection Behaviour

The operation of the protection on the Strathaven-Kilmarnock-Ayr No. 2 circuit was normal and correct. In the case of the No. 1 feeder, although both the main and backup protections at Strathaven operated correctly, the circuit breaker failed to open due to a fault in the tripping relay, the relay being common to both protections. Figure 1 attached shows the distribution of fault currents in the 275 kV. system following the clearance of the Strathaven-Kilmarnock-Ayr No. 2 feeder and also about 2 seconds after the start of the fault but prior to the loss of any generation. The overcurrent protection associated with the bus-coupler at Strathaven was not capable of responding to the initial fault current distribution.

However at 03.32 some 16 minutes after the Strathaven-Kilmarnock-Ayr No. 2 feeder had tripped the bus coupler and the Strathaven-Wishaw No. 2 circuit breaker operated. (Note that, although there were no flag indications on the overcurrent relay at the Wishaw end of this feeder, the relay is presumed to have operated because of the operation of the line trip relay). The time of operation of the bus coupler and Wishaw No. 2 circuit breaker at Strathaven has been agreed after interrogation of the engineer who went to Strathaven to open circuit breakers which it had been found impossible to operate by remote control. He has stated that he heard two circuit breaker operations when he was on the point of opening the sub-station gate. These could only have been the bus coupler and Wishaw No. 2 circuit breakers, as the only other circuit breaker which was closed at the time, namely the Kilmarnock-Ayr No. 1 circuit breaker, he subsequently opened manually. The estimates of the fault current in the bus coupler at 03.06 hours plus 2 seconds was marginally too small to operate the overcurrent relays and by 03.32 hours would become still smaller due to the loss of generating plant in Scotland and England. This effect may have been offset by an increase in the excitation of the remaining generators and also by the redistribution of fault current due to switching. The matter is still being investigated.

All the overcurrent relays at Strathaven and also the overcurrent relay on the Strathaven No. 2 feeder at Wishaw have been tested and found satisfactory.

The relay at Wishaw, which failed to drop its flag, was also tested at a current value only just sufficient to cause it to operate and it was found that it could then take up a position in which the contacts were touching but the flag did not drop. This would indicate that when the relays on the Strathaven-Wishaw No. 2 feeder operated the fault current value was such that their operation was marginal.

Two/

Two of the feeders involved, Neilston-Strathaven and Harker-Strathaven, are equipped with distance protection which might have been expected to operate. Figure 2 shows to scale the time/distance characteristics of these protections and also to the same scale their reach into adjacent circuits. Due to the fact that neither the Neilston circuit nor the Harker circuit was carrying the whole of the current in the faulty circuit their maximum reach was effectively shortened to the positions indicated and neither protection was therefore capable of operating to clear the fault.

Faulty Tripping Relay

The tripping relay on the Kilmarnock-Ayr No. 1 feeder at Strathaven which failed to operate was found to have an open circuited operating coil caused by a failure of the hand-resetting mechanism. The relay is a type F made by Reyrolle and is available in both hand and electrical reset versions. It is the subject of a C.E.G.B. Transmission Design Circular (No. 344 issued 7th October, 1969) which states that the extension arm of the hand reset feature may become distorted and cause the normally closed 'cut-throat' contact in the relay operating coil circuit to stay permanently open, rendering the relay inoperative. The circular states* that three courses of action are available for dealing with this defect namely:

(1) The relay may be inspected and adjusted. This will entail further constant vigilance whenever the relay cover has been removed.

(2) On relays which may be both hand or electrically reset, the hand reset mechanism may be removed.

(3) The hand reset mechanism may be changed for an improved design which the manufacturer now has available.

The circular was received in the Protection Section on or about 25th October and it was considered that course of action (1) was unacceptable as it was felt that it would be difficult to ensure a degree of vigilance which would be sufficient to ensure the integrity of the relay and that course of action (2) was also unacceptable, as hand-resetting of the relay would not only require removal of the cover but would also require a knowledge of the internal mechanism. It was therefore decided to follow course of action (3) and the initial steps in regard to this had already been taken before the fault occurred.

Action Taken Immediately Following the Fault

(1) Damage to Secondary Equipment

Due to the sustained nature of the fault, it was obvious that there must have been considerable overloading of secondary equipment (instruments, relays, current transformers, wiring and multicore cables). Evidence of such overloading was apparent at Strathaven, where instrument glasses were discoloured, and at Kilmarnock, where multicore tails showed softening of the insulation. Investigations have therefore been made into the serviceability of such secondary equipment and arrangements put in hand for its replacement where necessary.

(2) Reyrolle Type F8E/

* Copy attached to this Appendix.

(2) Reyrolle Type F8E

The hand-resetting knobs were removed from all Type F tripping relays on the transmission system on the day of the fault. This involved about 195 relays, two of which were found to be in a not very satisfactory condition.

(3) Reyrolle Type B Relays

These are subject to a similar defect to the type F relay and require similar treatment. The resetting knob has been removed from a total of sixteen relays but three associated with Supergrid Transformer T2 at Kilmarnock still remain to be modified (4.12.69). They will be dealt with as soon as it is safe to work on the transformer, i.e. when the Strathaven-Kilmarnock-Ayr No. 1 feeder is recommissioned.

(4) Reyrolle Type E Relay Elements

A draft T.D. Circular has been received from the C.E.G.B. since the fault and deals with a defect on type E relay elements. This is a moving coil relay element which is used in distance protection and intertripping. The draft states that information has been received that a plastic support for the fixed contact is liable to cracking and distortion thereby changing the contact gap and effectively increasing the setting of the relay. Inspection is called for and any supports which are observed to exhibit signs of cracking will need to be replaced. A total of 150 elements is involved and it is expected to complete inspection by 5th December, 1969.

Further Action Required

In the case of feeders which do not have duplicate main protection, but have instead main protection with backup overcurrent protection, arrangements are being made for the provision of a second tripping relay so that the two protections will not be dependent on a single tripping relay.

Arrangements have also been made to instal duplicate main protection on all circuits by the autumn of 1970/71.

275 kV. System Protection Policy

As the initial 275 kV. installations were in effect little more than an adjunct to the existing 132 kV. system, it was considered that there was no justification in applying protection to the standards which were then accepted by the C.E.G.B. for 275 kV. feeders. The protection arrangements therefore were in the main similar to those on the 132 kV. system, namely main protection with backup overcurrent although in recognition of the rather greater importance of these feeders, if only in terms of their MVA rating, standby protection was provided as well. This standby protection comprised two pole overcurrent and one pole earth fault definite time protection which was brought into service by a selector switch which disconnected the main protection when this became faulty and connected the standby protection.

This policy continued until 1965 when it was decided to adopt a policy using duplicate main protection based on C.E.G.B. Transmission Plant Standard 5/11 following which all Transmission Construction Authorisations for 275 kV. lines after June 1965, authorised two main protections. (The Strathaven/

Strathaven-Kilmarnock-Ayr feeders were commissioned in June-July, 1965). It was further agreed that, so far as the existing system was concerned, whenever any substation modifications or extensions were called for the opportunity would be taken to change the protection from main and backup with standby to two main protections.

In 1967, because the South of Scotland Electricity Board practice deviated from the C.E.G.B. practice as set out in Transmission Plant Standard 5/11, an S.S.E.B. standard (T.P.S.5/10001) was prepared and issued on 19.5.67.

It was soon realised that on the aforesaid basis, it would take too long to complete the installation of two main protections on the whole of the 275 kV. system and arrangements were therefore put in hand to obtain complete coverage by the winter of 1972/73. The progress which had been achieved towards this end is shown in Figure 3 and falls short of what was planned for 1969/70. This is mainly due to the system changes which were necessitated by the loss of the Clyde crossing in 1968. The position as now planned for the completion of the installation of two main protections by the autumn of 1970 is illustrated in Figure 4.

Future 275 kV. System Protection Policy

Some twelve months ago it was realised in the Protection Section that whilst the local backup protection on the 275 kV. system was in the main satisfactory the same was far from true in regard to remote backup protection in so far as operating times are concerned. The problem was examined, and as a result about six months ago a note was sent to the Transmission Design Engineer pointing out the desirability of either installing backup impedance protection or employing a scheme in which, if a feeder circuit failed to trip, the feeder protection tripping was converted to busbar tripping. In both cases, emphasis was placed on the more rapid clearance times that would therby be achieved thus ensuring system stability. The matter was again raised by the Protection Section in a note which was issued in September to the interested parties but again in the context of system stability. No progress has since been made, as the matter of operating times is not serious at the present juncture.

It is felt now that the consideration of remote backup protection must be dealt with on an urgent basis in relation to the problem of uncleared faults.

LIMITED CIRCULATION

CENTRAL ELECTRICITY GENERATING BOARD

TRANSMISSION DEPARTMENT

Transmission Design Circular No. [illegible]
(Protection) Issue [illegible]
Dated: 7 October 1969

Hand-Reset Tripping Relays Type 'F' and Type 'B' manufactured by A. Reyrolle & Co.

Foreword

Two failures to trip of 'F' type hand and electrically reset tripping relays have occurred. Non-operation of the relays was caused by the extension arm of the hand-reset feature becoming distorted and causing the normally closed "cut-throat" contact in the relay tripping-coil circuit to rest permanently open with the relay in the reset position.

Investigation has shown that the relay hand-resetting mechanism can give rise to a number of relay defects, of which open-circuiting of the series-break "cut-throat" contact is by far the most serious. However, on a number of relays, both on site, and in the manufacturers works, sticking reset buttons have been found. This means that the solenoid plunger may not complete its travel and open the "cut-throat" contact, the result being either a burnt out trip-relay coil or disintegration of the initiating relay contacts.

Similar difficulties with the hand-reset device have been experienced with Type 'B' relays, where distortion of the reset extension wire can permit fouling of the mechanism, and could result in a failure to trip.

Action

(1) Type 'F' Relays

This Transmission Design Circular applies only to relays manufactured prior to July 1969 when the reset mechanism was completely re-designed. (There may be some relays supplied prior to this date which have already been fitted with the new reset mechanism, but it is not possible to define these precisely).

For relays manufactured prior to July 1969 three courses of action are available:-

(a) The relay may be inspected and adjusted.
This will entail further constant vigilance whenever the relay cover has been removed.

(b) On relays which may be both hand or electrically reset, the hand-reset mechanism may be removed.

(c) The hand-reset mechanism may be changed for an improved design which the manufacturer now has available.

Details of the available methods of circumventing the problems produced by the hand-reset mechanism are as follows:-

Method (a)

It has been found that the profile of the button housing may have machining burrs left on, behind which the brass spring retaining screw may jam. If after removing the burr the mechanism does not return fully to the rest position a cure can sometimes be effected by dismantling the mechanism and increasing the reset spring pressure by tightening the spring by a half turn. Before removing the extension arm of the reset spindle its angular position should be carefully noted in order that it may be replaced in the same position. Having removed the extension arm the hexagonal securing nut can be loosened and the reset mechanism withdrawn. The brass spring retaining screw can then be removed, allowing the spindle to be rotated 180° thereby increasing the spring tension. Care should be exercised in performing this adjustment to ensure that the reset spindle is not withdrawn from the mechanism, merely rotated, otherwise initial adjustment will be lost, and re-assembly may prove difficult. This is not a universal solution and where spring tolerances are not sufficient to permit this, a new reset mechanism must be obtained from the manufacturer.

After reassembly of the reset mechanism the relay nameplate should be removed and the relay cover replaced and properly secured. The reset mechanism should be operated, and with the aid of a torch, a careful inspection made that the extension arm has an adequate clearance from the insulated arm which opens the "cut-throat" contact, even when the reset spindle is "waggled around". If necessary the reset extension arm (i.e. the formed piano wire) should be carefully bent until a satisfactory compromise is achieved between not fouling the "cut-throat" mechanism and failing to reset the solenoid plunger.

Method (b)

For relays which may be both hand and electrically reset the relays may be modified by the removal of the reset extension arm alone, or the removal of the complete reset mechanism including knob and spindle. This latter course will entail the fitting of a blanking button on the cover, and this may be obtained from A. Reyrolle & Co. The references for this component will be found under Method (c) below.

Method (c)

An adaptor bracket has been made available by the manufacturer and the method of mounting it is shown in Fig. 1.

The relay cover must be removed and both the flag and relay reset knobs removed. Blanking buttons for the holes are available from the manufacturer. The relay cover should then be rotated through 180° and redrilled in accordance with the appropriate Outline and Drilling Plan given in Table 1, when the new reset button can be fitted, together with the existing flag reset button.

The component references and drawing numbers for each type of 'F' relay necessary to perform this complete modification are given in Table 1.

TABLE 1

Component References and Drawing Numbers required for modification of reset mechanism of 'F' type tripping relays.			
For all 'F' type Relays	(1) Reset mechanism adapter bracket Art. No. 410A20120 (2) Blanking buttons Art. No. 410A3294W (3) Spire Clips Art. No. SFR1041/17/8		
Relay Ref.	Case	Reset Pushbutton	Outline & Drilling Plan
F8H or F8E	Single Pole Flush	Art.No. 410A19218	410A20081
	Single Pole Proj.	Art.No. 410A19218	410A20076
F8H	Draw out	Art.No. 410A20632	410A20085
F8E	Draw out	Art.No. 410A20632	410A20084
F14H or F14E	1½ Pole Flush	Art.No. 410A19218	410A20083
	1½ Pole Proj.	Art.No. 410A19218	410A12927Y
F14H	Draw out	Art.No. 410A20632	410A20087
F14E	Draw out	Art.No. 410A20632	410A20086

Additional Notes

On some relays a single reset device for both relay mechanism and flag is used, and for the modification of these relays a single blanking button is required, and the case must be redrilled to accept the modification detailed in Method (c).

All 'F' relays with a separate flag-reset mechanism should also be checked to ensure that the flag reset also returns to the fully reset position after operation to ascertain that it does not prevent the flag from falling. Any flag-reset mechanisms which exhibit a reluctance to fully reset should be inspected and adjusted as for the relay reset mechanism for which the instructions are given under Method (a) above.

Some difficulties have been experienced with the reset mechanism itself, relays occasionally being difficult to reset, or in very rare cases failing to reset. In the original design a single spindle was used to mount the armature of the reset coil and due to its being retained by splaying one end, the design could be prone to considerable stiffness. A new design has been incorporated since about 1964 which uses two short spindles to replace the single spindle. These short spindles are driven into the fixed member and the holes in the reset armature are a clearance fit allowing the reset armature free rotary movement. Any relays which prove troublesome on resetting, due to stiffness of reset armature, should be returned to the manufacturer for modification.

(2) Type 'B' Relays

The rotary hand-reset device on all hand-reset type 'B' relays should be checked, with the relay cover removed, that after operation it returns freely to the rest condition. If difficulty is experienced the reset device should be treated as for the 'F' relay under Method (a) above. If necessary a new rotary reset must be obtained from the manufacturer.

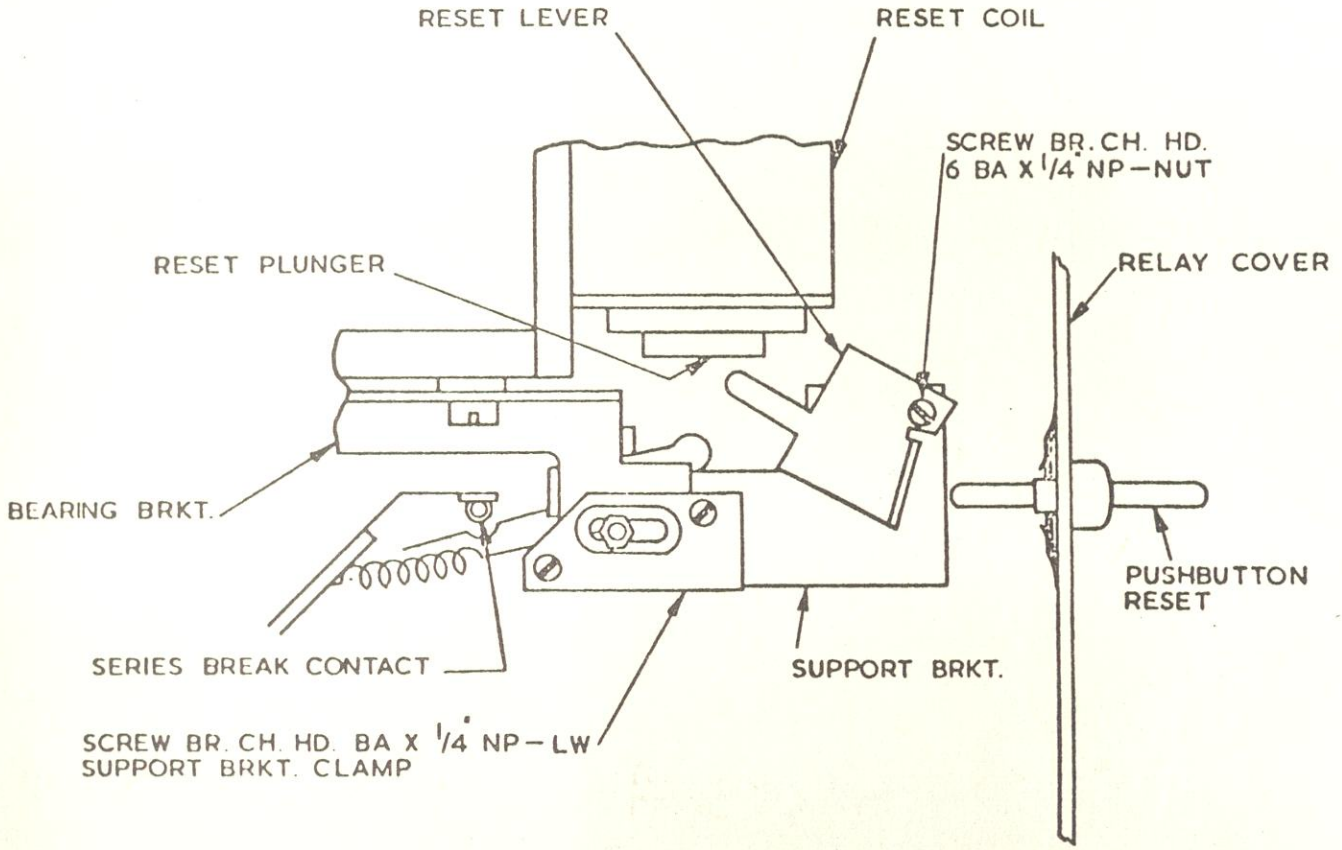
With the relay cover replaced and properly secured, and with the aid of a torch if necessary, the operated relay should be reset and it should be confirmed that adequate clearance is maintained between the rest extension arm and the relay mechanism, flag, and nameplate, consistent with obtaining a positive resetting of the relay. The reset extention arm should be adjusted to effect a suitable compromise.

(3) General Note

These latest difficulties further emphasize the importance of replacing the right cover on the right relay and this should be checked whenever a relay cover is removed. It is also extremely important, and particularly with draw-out and flush mounted relays, that relay covers are carefully treated at all times such that the reset mechanisms are not liable to be distorted through mishandling.

F. H. Last.

Transmission Development Engineer



NOTE :— RESET PLUNGER MUST NOT TOUCH SUPPORT BRKT.

FIG. 1 ASSEMBLY OF RESET ADAPTOR FOR HAND/ELECTRICAL RESET 'F' TYPE TRIPPING RELAYS

ALL LINE OVERCURRENT SETTINGS ARE 1600A - MINIMUM STARTING CURRENT 2070A

BUS COUPLER OVERCURRENT AT STRATHAVEN, SETTING IS 2000A CORRESPONDING TO OPERATION IN 15SECS WITH A CURRENT OF 2600

KILMARNOCK LINE OVERCURRENT SETTING IS 800A

AT STRATHAVEN

ALL MAIN PROTECTIONS ARE UNIT-TYPE

EXCEPT NEILSTON AND KILMARNOCK CIRCUITS

WHICH ARE DISTANCE

S - OPENED BY SUPERVISORY
H - OPENED BY HAND (LOCALLY)
P - OPENED BY PROTECTION

DISTRIBUTION OF FAULT CURRENT

a. DURING TRANSIENT CONDITION SHOWN THUS - 2340

b 2 SECS. AFTER FAULT OCCURRED USING SYNCHRONOUS REACTANCE SHOWN THUS -(1282)

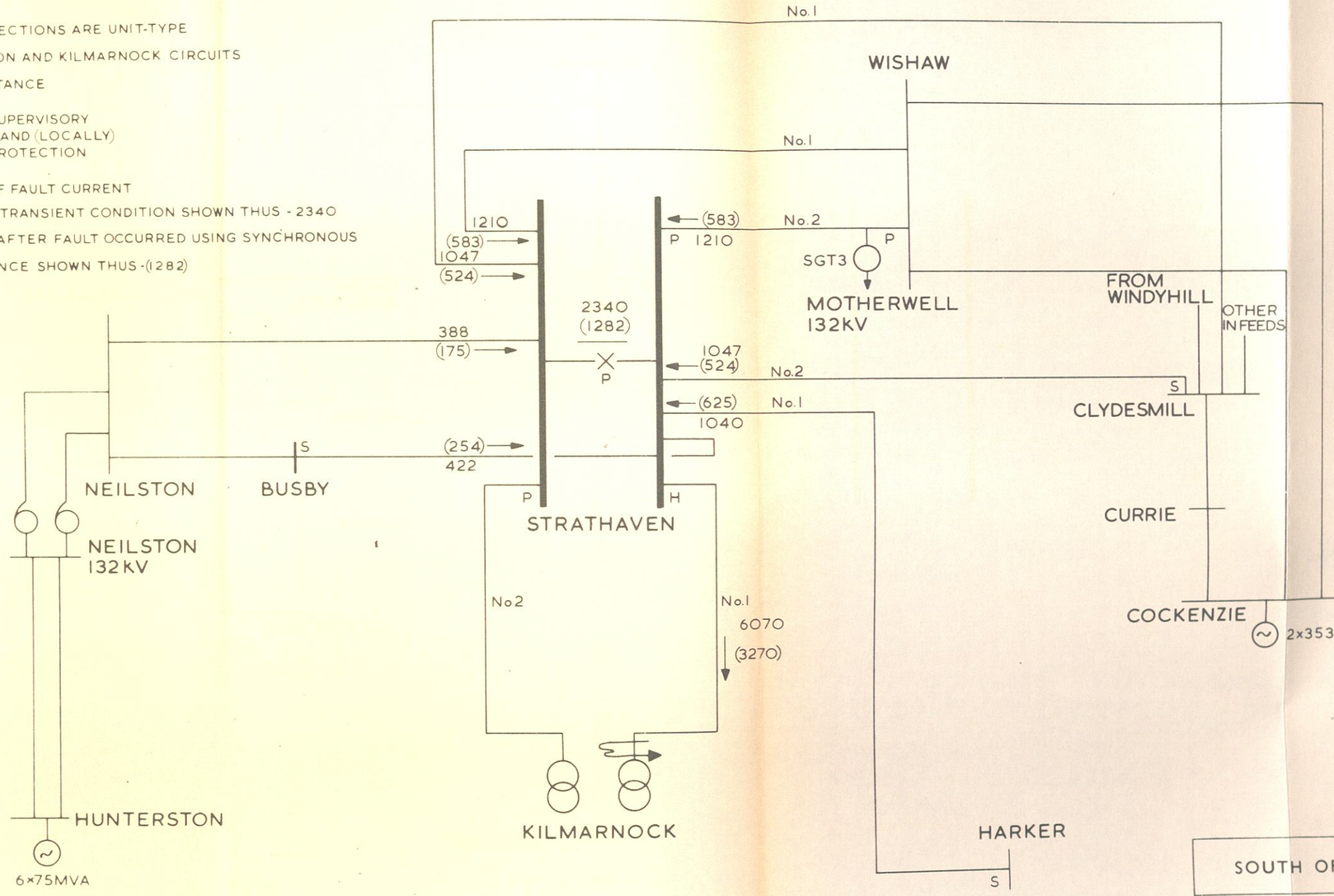


FIG. 1

SOUTH OF SCOTLAND ELECTRICITY BOARD

TITLE

DISTRIBUTION OF FAULT CURRENT

D	DATE / DRAWN / APPRD.	C	DATE / DRAWN / APPRD.	B	DATE / DRAWN / APPRD.	A	DATE / DRAWN / APPRD.

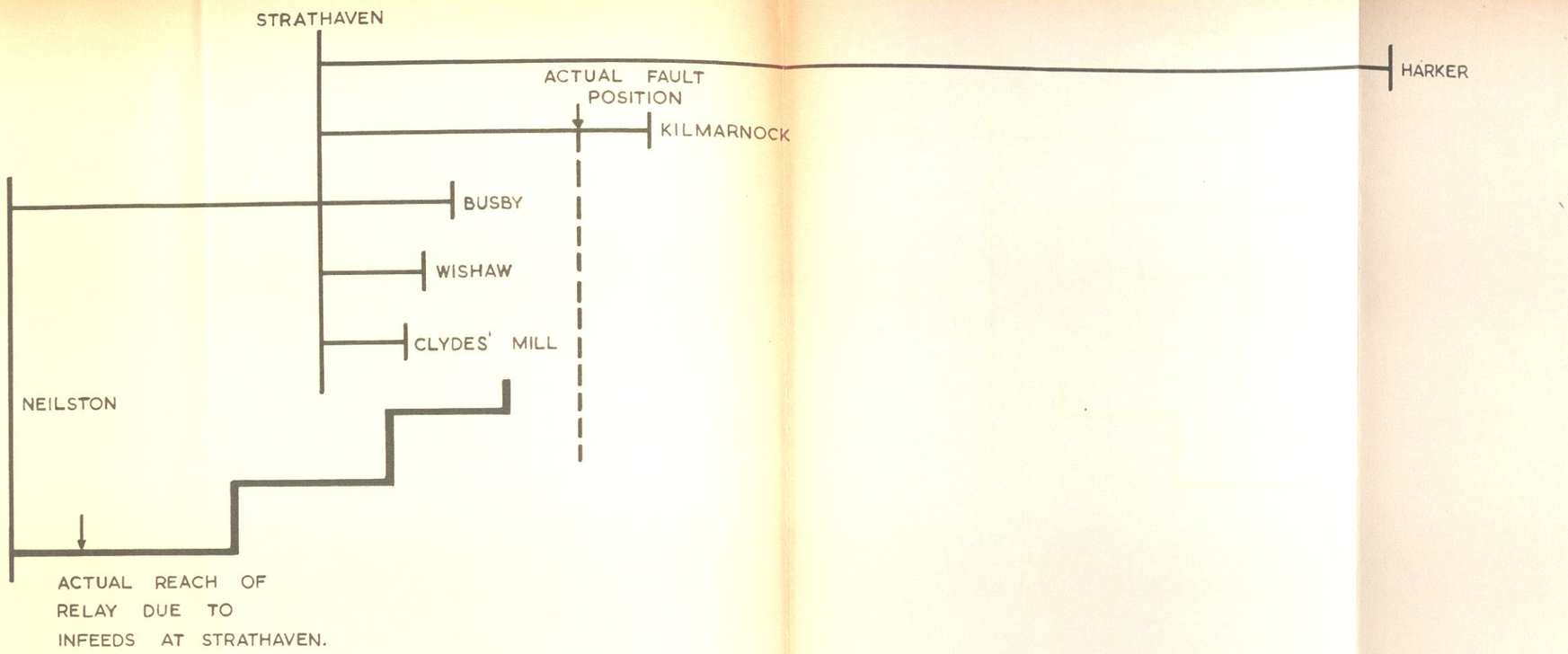
No. OF SHEETS	
SHEET No.	
OFFICE OF ORIGIN	
SECTION	
STATION	

SCALE

DRG. No. PSK.398

REVISION

DRAWN	TRACED	CHECKED	APPRD.	ENGR.
	E.C.A.			
	3·3·70			



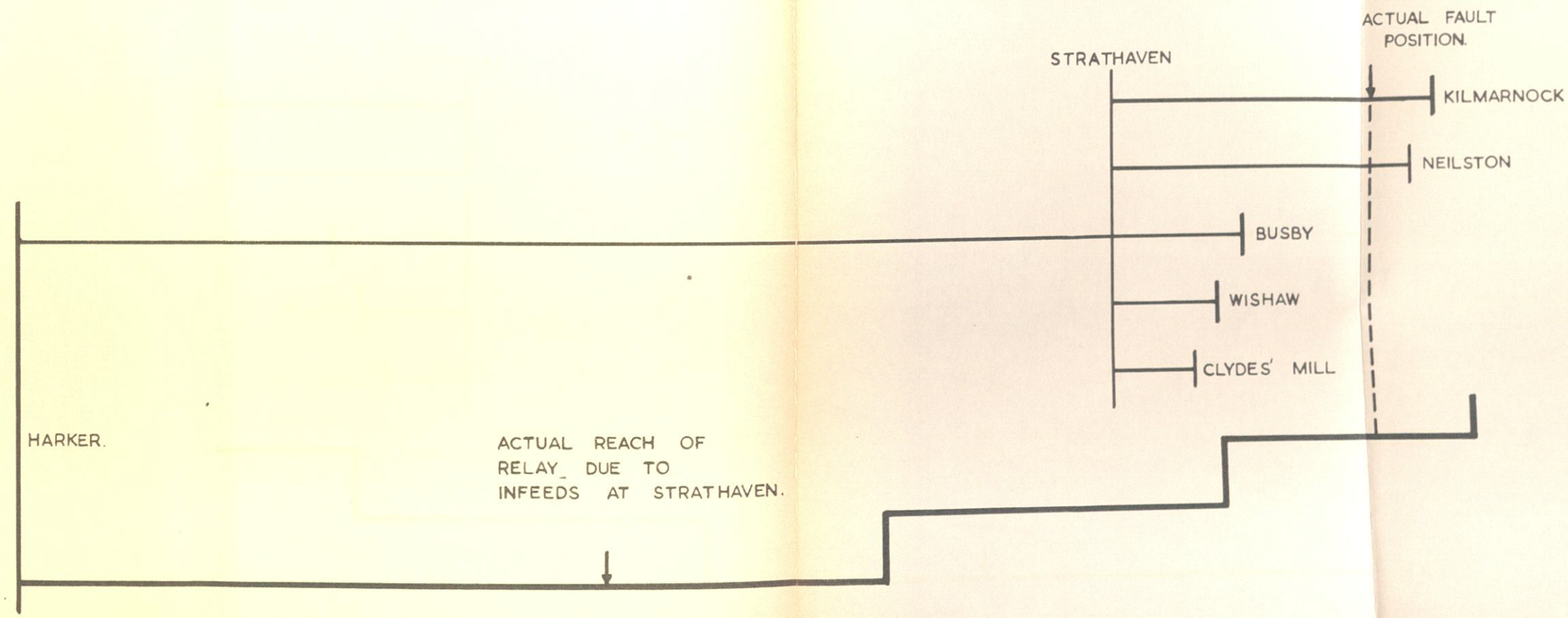


DIAGRAM ILLUSTRATING
'UNDER - REACHING' OF DISTANCE PROTECTIONS AT NEILSTON & HARKER.

FIG. 2

PSK 399

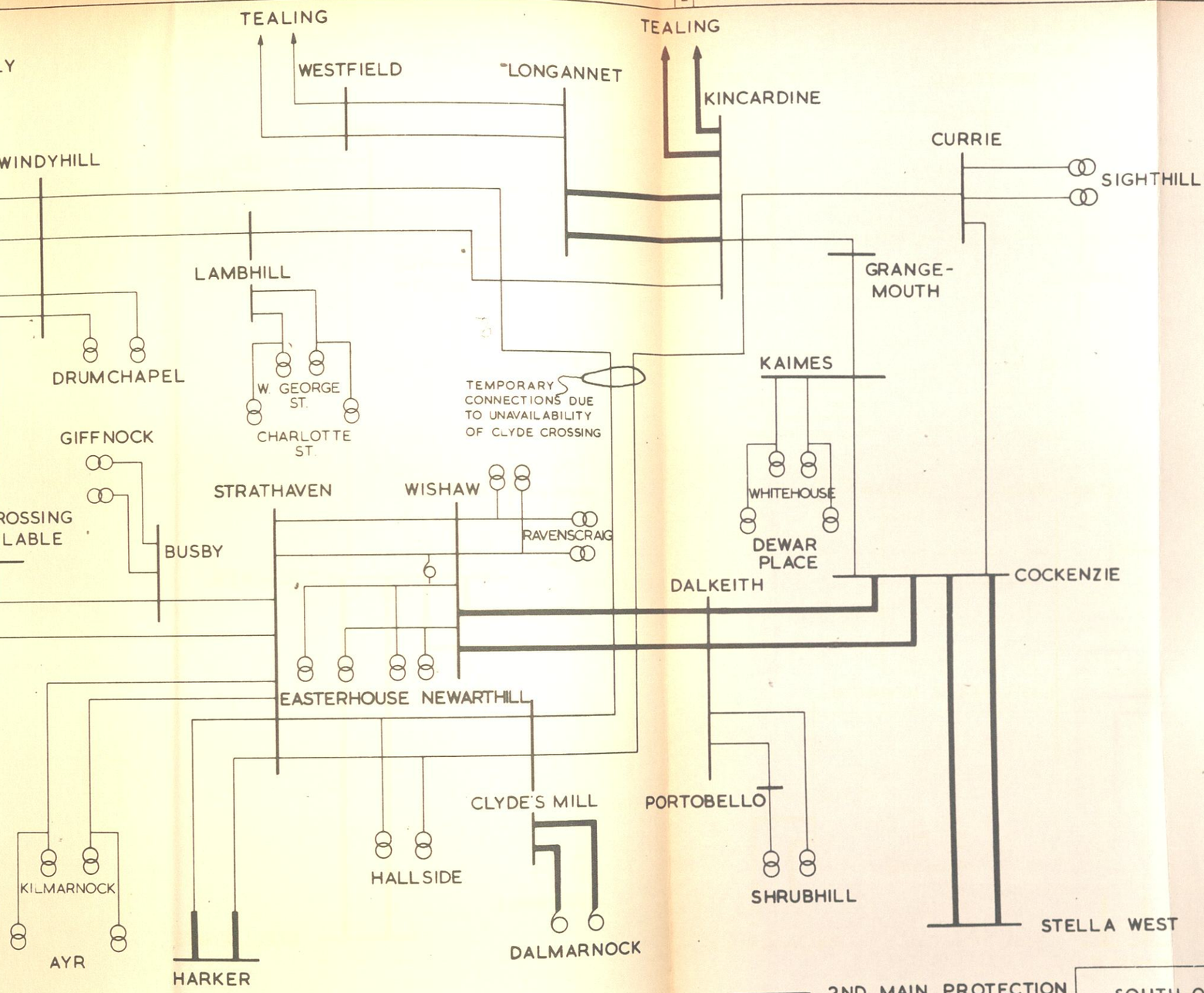


FIG. 3

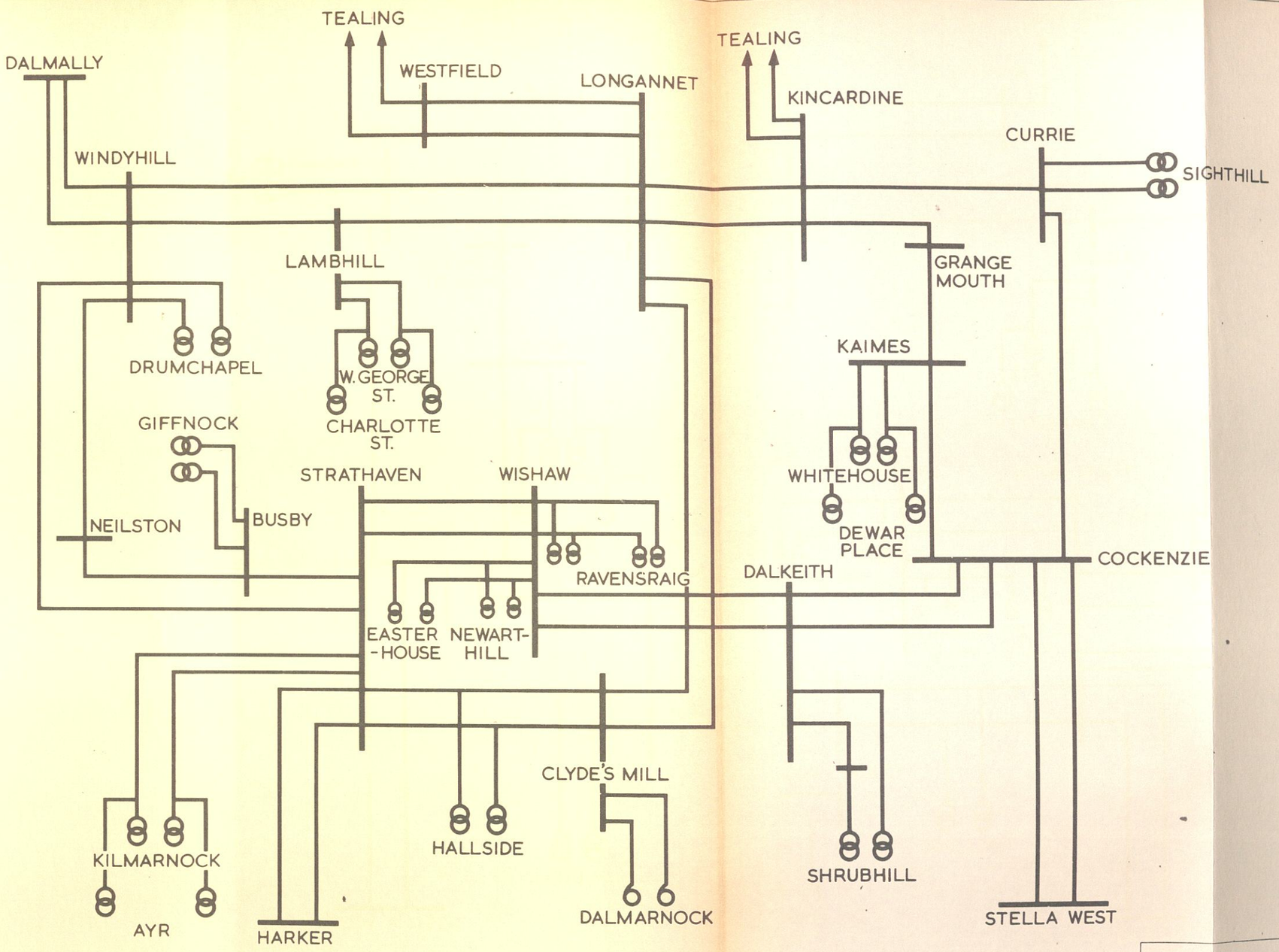
SOUTH OF SCOTLAND ELECTRICITY BOARD

TITLE
275kV SYSTEM AT TIME OF STRATHAVEN–KILMARNOCK FAULT
03·05 HRS .8TH NOVEMBER 1969, SHOWING
CIRCUITS EQUIPPED WITH TWO MAIN PROTECTIONS

No. OF SHEETS		SCALE	
SHEET No.		DRG. No. PSK. 400	
OFFICE OF ORIGIN		REVISION	
SECTION			
STATION			

	DRAWN	TRACED	CHECKED	APPRD.	ENGR.
		B.J.B.			
		3·3·70			

	D	C	B	A
DATE				
DRAWN				
APPRD.				



2ND MAIN RROTECTION IN SERVICE.

FIG. 4

SOUTH OF SCOTLAND ELECTRICITY BOARD

TITLE

275kV. SYSTEM AS AT WINTER 1970/71, WHEN ALL CIRCUITS WILL BE EQUIPPED WITH TWO MAIN PROTECTIONS.

D	DATE / DRAWN / APPRD.	C	DATE / DRAWN / APPRD.	B	DATE / DRAWN / APPRD.	A	DATE / DRAWN / APPRD.

No. OF SHEETS

SHEET No.

OFFICE OF ORIGIN

SECTION

STATION

SCALE

DRG. No. PSK. 401

REVISION

DRAWN	TRACED	CHECKED	APPRD.	ENGR.
	G.C.			
	3-3-70			

APPENDIX VIII

System Fault Saturday, 8th November, 1969

Telecommunications Report

1. General Position

1.1 Grid Control Centre

At the commencement of the fault correct indications were received at C.I.S. and Area Control (Kilmarnock) of 33 kV. O.C.B. operations at Kilmarnock. From the log-sheets at C.I.S. and Clyde's Mill it would appear that no circuit breaker indications were received from Strathaven.

The total number of indications received at C.I.S. was very considerable since all generation tripped and since the various manned points took emergency action and tripped a large number of L.V. breakers. It would appear that all General indicating equipment and grid control telephony at C.I.S. behaved correctly with the exception of Cruachan, which at times was rendered inoperative by excessive noise and referred to in Section 4.1. There were failures of communication equipment at the outstations due to loss of supply as referred to later, and due to conjestion there was difficulty in telephone communication with C.I.S.

1.2 Kilmarnock

At the commencement of the fault correct indications were received on the 275 kV. direct wire control board. Later however a number of spurious alarms were displayed. This was later found to be due to short circuits on the multicore cabling between the 275/33 kV. sub-station and the Area Control Room. A small number of lamps on the alarm facia were found to have blown due presumably to induced voltage in the multicores and one fuse associated with the group load-shed control was blown by a full earth appearing on the associated multicore cable. The tap change control from the Power Station Control Room was inoperative during the fault and this was subsequently found to be due to the fitting of the wrong coil in an interposing relay. This relay must have operated marginally for some time.

All other supervisory equipments at Kilmarnock behaved correctly.

1.3 Strathaven-Clyde's Mill

Strathaven is remotely controlled from Clyde's Mill and circuit breaker indications are repeated from the supervisory control equipment to the Clyde's Mill - C.I.S. general indicating equipment. Investigation has shown that the supervisory equipment failed due to a lock-up caused by incorrect conditions being presented by the Kilmarnock No. 1 protection operated indications.

The main and back-up protection associated with H115 operated correctly and initiated indications to the supervisory equipment. Such protection indications are however normally of the fleeting type since the protection relays are re-set within a few milliseconds of the operation of the tripping relay. It is necessary therefore that the fleeting indications be stored in the supervisory equipment to give time for them to be transmitted to the control station. This is achieved by a fast/

fast operating relay which locks up to one of its own contacts until the indication train has been marked, when it is force released. On this occasion due to the non-operation of the tripping relay the fleeting contact became persistent. When therefore the storage relay released it was still presented with the alarm condition and re-operated.

This process continued indefinitely with the result that the first group of indications was repeated continuously. As a result indications in other groups (which included circuit breakers H85, L50, L60 and W10) could not be transmitted to Clyde's Mill and thence to C.I.S.

The C.E.G.B. and S.S.E.B. specifications for remote control equipment stipulate that incoming indications should take priority over control functions (CCS1960 Section 4, para. 4.18.7).

All supervisory equipments are therefore designed in such a way that control functions are inhibited while indications are being received. The Control Engineer at Clyde's Mill would therefore be unable to make use of this equipment to open any of the Strathaven circuit breakers until Mr. Petrie opened breaker H115 at Strathaven releasing the protection relays.

1.4 Ayr

Ayr District Office P.A.X. has no 50 V. battery and the loss of a.c. supplies to the inverter caused serious communication difficulties. All Area and Transmission staff were forced to use Ayr Substation for all telephone purposes.

All Area Radio System and the Transmission Radio System were also out of action due to the loss of the M.V.a.c. supply.

1.5 Windyhill 132/275 kV. Control Room

Numerous alarms appeared on the 132 and 275 kV. control boards although no O.C.B. tripped. When load shedding using the supervisory equipment the only difficulty occurred when an attempt was made to trip Killermont 33 kV. circuit breakers and was unsuccessful on the first attempt probably because enough time was not allowed to give equipment time to complete tripping operation.

The G.I. line from C.I.S. to Cruachan via East Power Line Carrier was troublesome due to extreme noise. The West Power Line Carrier system was not so noisy and the G.I. line was transferred from the East to West system but still proved unsatisfactory and was finally transferred to Channel 3 West Power Line Carrier.

A Telecommunications alarm was received from Helensburgh due to the loss of the a.c. supply to 50 V. and 80-0-80 chargers, this was remedied later by restoring a.c. supply.

1.6 Port Dundas

A Telecommunications alarm was reported and found to be due to a V.T. Fail at Port Dundas.

1.7 Neilston

1.8 West George Street Area Control Room

When carrying out load shedding the control engineer successfully opened No. 1 33 kV. transformer circuit breakers at Govan, St. Andrews Cross and Haggs Road but was unable to open the No. 2 transformer circuit breakers at these substations probably because enough time was not allowed for the equipment to complete the tripping operation. Alarms were received from supervisories at Lambhill, Charlotte Street and Carntyne.

2. Investigation

2.1 Equipments Involved

Investigation has shown that a similar indication lock-out to that which occurred at Strathaven, could occur on all supervisory equipment of G.E.C. manufacture of which the S.S.E.B. have about 25 systems installed. Equipment of Plessey (A.T. & C. Co.) and S.T. & C. manufacture employ different circuitry and would not lock-out under similar conditions.

Whilst a sustained fault may be a very rare occurrence it is obvious that a permanent earth or short circuit on the multicore cabling connected to fleeting alarm points in G.E.C. equipment would cause the same trouble and it is essential that measures be taken to modify all circuits of this type. The total number of these indication points in service may be of the order of 200 and unless a very simple modification is possible it will take some considerable time and effort before all systems can be modified.

2.2 Modifications to Supervisory Equipment

The circuit arrangement of the G.E.C. supervisory equipment has been examined in detail and proposals for correcting the fleeting alarm lock-up have been submitted to the contractors for comment. Supervisory equipment, however, which must selectively select a large number of functions on a common communication channel, has somewhat complex circuitry and a large amount of common selection equipment. There is considerable danger therefore that any precipitate action taken to clear trouble on one part of the system may have adverse effects on other functions.

It is proposed therefore that as soon as the corrective measures are agreed between the contractors and ourselves, one of the smaller supervisory systems will be modified and thoroughly tested. If successful the modifications will be carried out on the remaining equipment in turn. It is probable that it will take some 3/4 months to carry out this work but the actual time will depend on the extent of the modification.

Since the solution of the fleeting alarm problem may involve resetting from the control station end, it is hoped that the problem of ensuring that control functions can be permitted to proceed will be solved at the same time.

Discussions have been held with various sections of C.E.G.B. Since the original specification for remote control equipment was written many years ago and since the clause calling for indication priority has been repeated through various issues it has not been possible to determine whether it was introduced as a matter of policy or as a necessity resulting from the design of early 2-wire signalling systems.

Opinion/

fast operating relay which locks up to one of its own contacts until the indication train has been marked, when it is force released. On this occasion due to the non-operation of the tripping relay the fleeting contact became persistent. When therefore the storage relay released it was still presented with the alarm condition and re-operated.

This process continued indefinitely with the result that the first group of indications was repeated continuously. As a result indications in other groups (which included circuit breakers H85, L50, L60 and W10) could not be transmitted to Clyde's Mill and thence to C.I.S.

The C.E.G.B. and S.S.E.B. specifications for remote control equipment stipulate that incoming indications should take priority over control functions (CCS1960 Section 4, para. 4.18.7).

All supervisory equipments are therefore designed in such a way that control functions are inhibited while indications are being received. The Control Engineer at Clyde's Mill would therefore be unable to make use of this equipment to open any of the Strathaven circuit breakers until Mr. Petrie opened breaker H115 at Strathaven releasing the protection relays.

1.4 Ayr

Ayr District Office P.A.X. has no 50 V. battery and the loss of a.c. supplies to the inverter caused serious communication difficulties. All Area and Transmission staff were forced to use Ayr Substation for all telephone purposes.

All Area Radio System and the Transmission Radio System were also out of action due to the loss of the M.V.a.c. supply.

1.5 Windyhill 132/275 kV. Control Room

Numerous alarms appeared on the 132 and 275 kV. control boards although no O.C.B. tripped. When load shedding using the supervisory equipment the only difficulty occurred when an attempt was made to trip Killermont 33 kV. circuit breakers and was unsuccessful on the first attempt probably because enough time was not allowed to give equipment time to complete tripping operation.

The G.I. line from C.I.S. to Cruachan via East Power Line Carrier was troublesome due to extreme noise. The West Power Line Carrier system was not so noisy and the G.I. line was transferred from the East to West system but still proved unsatisfactory and was finally transferred to Channel 3 West Power Line Carrier.

A Telecommunications alarm was received from Helensburgh due to the loss of the a.c. supply to 50 V. and 80-0-80 chargers, this was remedied later by restoring a.c. supply.

1.6 Port Dundas

A Telecommunications alarm was reported and found to be due to a V.T. Fail at Port Dundas.

1.7 Neilston

The Strathaven acceleration (Brown Boveri) "fail" alarm operated at 6.30 a.m.

1.8 West George Street Area Control Room

When carrying out load shedding the control engineer successfully opened No. 1 33 kV. transformer circuit breakers at Govan, St. Andrews Cross and Haggs Road but was unable to open the No. 2 transformer circuit breakers at these substations probably because enough time was not allowed for the equipment to complete the tripping operation. Alarms were received from supervisories at Lambhill, Charlotte Street and Carntyne.

2. Investigation

2.1 Equipments Involved

Investigation has shown that a similar indication lock-out to that which occurred at Strathaven, could occur on all supervisory equipment of G.E.C. manufacture of which the S.S.E.B. have about 25 systems installed. Equipment of Plessey (A.T. & C. Co.) and S.T. & C. manufacture employ different circuitry and would not lock-out under similar conditions.

Whilst a sustained fault may be a very rare occurrence it is obvious that a permanent earth or short circuit on the multicore cabling connected to fleeting alarm points in G.E.C. equipment would cause the same trouble and it is essential that measures be taken to modify all circuits of this type. The total number of these indication points in service may be of the order of 200 and unless a very simple modification is possible it will take some considerable time and effort before all systems can be modified.

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The circuit arrangement of the G.E.C. supervisory equipment has been examined in detail and proposals for correcting the fleeting alarm lock-up have been submitted to the contractors for comment. Supervisory equipment, however, which must selectively select a large number of functions on a common communication channel, has somewhat complex circuitry and a large amount of common selection equipment. There is considerable danger therefore that any precipitate action taken to clear trouble on one part of the system may have adverse effects on other functions.

It is proposed therefore that as soon as the corrective measures are agreed between the contractors and ourselves, one of the smaller supervisory systems will be modified and thoroughly tested. If successful the modifications will be carried out on the remaining equipment in turn. It is probable that it will take some 3/4 months to carry out this work but the actual time will depend on the extent of the modification.

Since the solution of the fleeting alarm problem may involve resetting from the control station end, it is hoped that the problem of ensuring that control functions can be permitted to proceed will be solved at the same time.

Discussions have been held with various sections of C.E.G.B. Since the original specification for remote control equipment was written many years ago and since the clause calling for indication priority has been repeated through various issues it has not been possible to determine whether it was introduced as a matter of policy or as a necessity resulting from the design of early 2-wire signalling systems.

Opinion/

Opinion in the C.E.G.B. regarding the desirability of changing the specification is mixed, some sections arguing for its retention while others, mainly operational, consider that the inhibition should be removed.

3. Multicore Cables

3.1 Kilmarnock

All faulty multicore cabling has now been disconnected from the direct wire control equipment and controls and indications associated with the No. 2 line and all common controls and indications are working correctly.

A number of the multicore cables from the substation marshalling kiosks have been carrying very heavy sheath currents and a number of cores in them were charred and/or welded together. At the gland plates of the substation junction box considerable arcing had occurred resulting in heat transfer to the 37 core pilot cables where minor damage is apparent on the outer P.V.C. sheath. These cables have been meggered and pressure tested (2.5 kV) and apart from the sheath damage appear to be in good condition.

It will be necessary to replace a number of the smaller multicores in the substation and to cut back and reterminate the 3-37 pair pilots. This operation will require to be carried out in two stages since the No. 2 circuit connections must be kept intact until the No. 1 circuit is re-commissioned.

There is also evidence that cables carrying Distribution Controls and indications to the 33 kV. control panels in the Distribution Control Room have been subjected to excessive sheath currents. These and other cables lying near them in the Control Room are being examined and may require replacement.

3.2 Strathaven

No telecommunications equipment or cabling was damaged at Strathaven.

4. Communications - Investigations

4.1 Kirkintilloch - Cruachan - Port-na-Craig

Problems associated with the Cruachan power line carrier channels have been discussed with the H.E.B. It would appear that the Cruachan system is the only 275 kV. P.L.C. system used for telecommunication purposes in this country and no operating experience is therefore available for comparison purposes. The H.E.B. have a large number of speech and signalling circuits on their 132 kV. system but state that while the noise level may rise considerably under certain weather conditions, this does not normally make the circuits unusable. No serious difficulties were experienced with P.L.C. on the 132 kV. system on the night of the fault.

Since the preliminary report was issued it has been ascertained that both the telephony and indications system operated satisfactorily during the time that the fault persisted. The telephone channel was again used some time after the clearance of the fault. This being the/

the case the interference could not have been caused by high frequency noise generated by the fault itself. The fact that the noise was most severe at the time of excessively high system voltage suggested that it was due to corona effects, but subsequent tests showed that this was not the cause.

It is not of course practicable to reproduce conditions to prove or disprove the above theory and it may be several years before sufficient evidence can be obtained to ascertain the security, or otherwise, of carrier communications channels on the 275 kV. system.

To reduce the chances of losing all communications with Cruachan in future it would be advisable to introduce some diversity (at present both H.E.B. and ourselves rely on the P.L.C.). It has been ascertained that the Post Office could now provide a good quality circuit (underground all the way) between Kirkintilloch and Cruachan and it is recommended that the S.S.E.B. should order such a circuit forthwith.

4.2 Barony and Tongland

Investigation into an alleged loss of telephonic communication at Barony and Tongland suggests that no failure of lines or equipment occurred and that the various calls were simply not answered due to pressure of work in the Control Centres.

The engineer at Barony has stated that he made calls on the Control, Post Office and Private Automatic Systems to both Grid Control and Kilmarnock. In all cases the system operated correctly and ring-back tones were heard. Calls to other external points, e.g. Barony Colliery were completed satisfactorily.

The Control Engineer at Tongland made one call to Grid Control at about 03.07 a.m. Ring-tone was heard but the call was not answered.

Neither Barony nor Tongland made use of priority facilities on the Grid Control telephone system.

4.3 Radio Transmitters

Radio transmitters were fitted at a number of Generating Stations some years ago, initially as a Civil Defence requirement. In all cases the work was carried out on a shoe-string budget and no separate standby power supplies were installed. All transmitters and remote control units were connected to the most secure supplies available. With the exception of Tongland it is believed that all radio equipped power stations now have standby diesel generators. Since the radio equipment at Dalmarnock and Clyde's Mill failed, due to lack of power supply, a check is to be carried out to ensure that the radio equipments do in fact get a standby supply from the diesel generators.

All main V.H.F. radio stations on the Grid Transmission system have standby power supplies but a number of U.H.F. links and remote control terminals at Transmission Group Offices do not.

It is estimated that the cost of providing standby supplies for radio for all sites where diesel standby does not already exist would be about £7/800 for all and a decision on the policy to be adopted in future is required.

4.4/

4.4 Telegraph

The present telegraph system is limited to sixteen points which are shared between load shedding and Generation instructions. All points are at present in use. The only logical way to increase the availability of the telegraph system would be to provide separate instructors for generation and load shedding purposes. Many of the generating stations are still concerned with load shedding either on their local L.V. busbars or because they are remotely operating distant L.V. supply points. Such stations would therefore require both telegraph systems. At the same time desk accommodation is in general severely restricted in control rooms.

In view of the above and since a loudspeaking broadcast system is already on order for the new Grid Control Centre, I understand that Mr. Davies proposes to drop this proposal.

4.5 Separation of Indication and Control Functions

Of the major 275 kV. substations on the Transmission System Windyhill, Neilston, Clyde's Mill, Kincardine, Longannet, Cockenzie and Kaimes are all manned with direct wire control facilities and with General Indication and Telemetering systems to Grid Control. General Indication equipment for Strathaven, Wishaw and Westfield and Currie was authorised under the new Grid Control Centre Project, is at present on order and will be commissioned along with the new G.C.C. The remaining substations in the main transmission system (Busby, Lambhill, Grangemouth and Dalkeith) are all small. None of these require telemetering, all have adequate telephone facilities over pilots from adjacent major stations and none of them have more than 3 grid circuit breakers. None of these can therefore justify direct circuits to grid control. The cost of providing the normal general indicating equipment direct to the Grid Control Centre would be about £5,000 for each station.

To ensure that the complete 275 kV. transmission network is separately indicated to C.I.S. and to the control point it may be worth considering the provision of small indicating systems to ferry these circuit breaker indications to an adjacent major station other than the control point for onward transmission to C.I.S. It should be possible to provide such systems for about £1,000 each or possibly less if certain redundant equipment from the present Grid Control Centre can be re-used.

S.A. Soutter
Telecommunications Engineer

APPENDIX IX

Major System Fault - Saturday, 8th November, 1969

S.S.E.B. Consumers Complaints of Damage or Loss

GLASGOW/CLYDE AREA

Letters received from the following consumers:-

Glasgow North District

1.	Shettleston Co-operative Soc., Shettleston Road.	Considerable damage to oil fired heating unit.
2.	Capital & Counties Property Co. Ltd., Marland House, George Street. (Also letter from Jas. Kilpatrick & Son Ltd.)	150 contactors on heating panels damaged.
3.	Scottish Gas Board, Provan Works.	Serious loss of gas production.
4.	Wm. Beattie Ltd., 116 Paton Street.	Abnormal M.D. reading. Loss of production and coils burnt out.
5.	Scottish Special Housing Assoc. Ltd., Multi-Storey Flats) Various Addresses)	Fan motors burnt out. Starter units and O/L units damaged.

Glasgow South District

Letters have been received from the undernoted domestic consumers:-

1.	W. Marriott, Newton Mearns.	Damage to floor warming installation.
2.	Scottish Special Housing Assoc. Ltd., Multi-Storey Flats, 341 Caledonia Road.	Fan motor burnt out.

In addition, the following consumers have made verbal complaints to the District Engineer:-

1.	Scottish Special Housing Assoc.	Damage to plant, motors and starting gear at various sites (unspecified).
2.	G.P.O. Savings Bank, Cowglen.	Damage to air conditioning control gear and consequential damage to refrigeration plant.
3.	Lyons Bakery, Elderpark Street.	Control gear coils burnt out and possibility of other damage.
4.	Scottish Gas Board, Tradeston.	Report of "Danger and Upheaval" by interrupting gas making and distribution processes.

Paisley District/

Paisley District

Letters have been received from the following consumers:-

1.	Davie & McCulloch, 11 Elmbank Street.	Damage to relay and clock wiring of boiler-house control panel at New Sandyford Church, Gallowhill, Paisley.
2.	Scottish Gas Board, Western Group, Paisley.	Complaint regarding possible loss of gas supply to Paisley town.

No reports have been received at the Greenock & Clydebank Districts.

CENTRAL AND SOUTH WEST SCOTLAND AREA

1.	British Airports Authority, Prestwick, Ayrshire, Scotland.	Both in-take substations at the airport were affected.
2.	Scottish Gas Board, West-Central Group, Bothwell Road, Uddingston.	Prolonged stoppage of electrical power at Uddingston gasworks.
3.	Scottish Gas Board, Western Group, Riverbank Gas Works, Kilmarnock.	Failure of power at Riverbank Gas Works.
4.	Mr. Guthrie, West Mosside Farm, Kilmarnock.	Kilmarnock South/Kilmarnock 275 kV. line runs across farm. Cattle found dead or ill in vicinity of tower 8.

EDINBURGH, FIFE AND BORDERS AREA

1.	G.P.O. Telecommunications Hdrs. Scotland, Canning House, 19 Canning Street, Edinburgh.	Damage to Post Office Telecommunication Dept., equipment.

APPENDIX X

D.I. 9/1

SOUTH OF SCOTLAND ELECTRICITY BOARD

ENGINEERING INSTRUCTION NO. EI/134 (2ND REVISION)
(Limited Circulation)

System Operation Memoranda Nos. 15A, 15B and 15C
Load Shedding in the event of exceptionally
Serious Breakdown on the Grid System

Purpose:

(1) This Instruction deals with emergency load shedding arrangements in the event of exceptionally serious breakdown on the grid system and is a revision of EI/134 (revised) dated 10th July, 1962.

(2) C.E.G.B. Revision of Emergency Load Shedding

Procedure

The Station Superintendents' Meeting of 14th December, 1965, approved a C.E.G.B. paper on the revision of Emergency Load Shedding Procedure. At the Area Engineers' Meeting held on 6th January, 1966, the Chief Transmission/ Distribution Engineer recommended that the relevant EI/134 be amended in line with this revision and issued without delay.

(3) The instructions which deal separately with generating stations, substations and generating stations without local supplies are attached as Appendix No. 1, Appendix No. 2 and Appendix No. 3 respectively to this Instruction.. Copies mounted on cards are suitable for placing in a prominent position in Control Rooms.

Scope of Appendix No. 1 (Generating Stations with local supplies)

(4) The Control Room staff at generating stations will be required to follow the instructions laid down in this Appendix in the event of a serious drop of frequency on the system, without prior warning to the Grid Control Engineer or to the Areas. The Grid Control Engineer should however be informed of any action taken as soon as possible thereafter. The procedure for dealing with such an emergency has already been agreed and it is only necessary for Area Engineers to review the instructions already given to Generation Stations' staffs for emergency switching in steps of 20%. The instructions should be sent in triplicate to the Chief Engineer's Department. One of the copies will then be sent to the Generating Engineer (Operation) with a further copy for the System Operation Engineer. So far as possible feeders have been, or will be, arranged so that domestic and other less essential loads are disconnected first. Feeders supplying collieries and other essential loads should be the last to be disconnected.

Scope of Appendix No. 2 (Substations)

(5) Instructions as to the order in which the load shedding referred to in this Appendix shall be carried out, will come from the appropriate Area Engineer. It is important that Area Engineers who have continuously staffed substations under their control should ensure that the operating staffs have copies of this document available to them and are fully conversant with the procedure to be adopted in the event of a sudden drop in frequency to 48.5 cycles per second or lower. As in the case of Generating Stations, the sequence with which feeders would be switched out in approximately 20% steps must be given to the operating staff by the Area Engineer, the less essential feeders being/

being the first to be switched out. Copies of the Area Engineers' instructions to the operating staff of the continuously manned sub-stations where emergency load shedding is to be carried out, should be sent in triplicate to the Chief Engineer's Department. One of the copies will then be sent to the Generation Engineer (Operation) with a further copy for the System Operation Engineer.

Scope of Appendix No. 3 (Generating Stations without Local Supplies)

(6) The Control Room staff at generating stations will be required to follow the instructions laid down in this Appendix in the event of a serious drop of frequency on the system, without prior warning to the Grid Control Engineer of to the Areas. The Grid Control Engineer should however be informed of any action taken as soon as possible thereafter.

H. MORRIS
Chief Engineer.

SOUTH OF SCOTLAND ELECTRICITY BOARD

ENGINEERING INSTRUCTION NO. EI/134 (2ND REVISION)

APPENDIX NO. 1

OPERATION MEMORANDUM NO. 15A

(Generating Stations with Local Supplies)

EMERGENCY LOAD SHEDDING

in the event of

EXCEPTIONALLY SERIOUS BREAKDOWN ON THE GRID SYSTEM

The Control Room Operator at the Generating Station MUST act as follows:-

LOAD SHEDDING

1.* IF THE SYSTEM FREQUENCY FALLS to 48.5 Hz low frequency relays will cause load to be shed in a pre-arranged step of 20%. Thereafter if the system frequency continues to fall the low frequency relays will shed a further 30% of load at 48.0 Hz.

2.* If the frequency continues to fall the Control Room Operator at the Generating Station must continue to shed load manually in pre-arranged steps in order to prevent the frequency falling below 47.0 Hz.

3. All the pre-arranged steps of load must have been shed when the frequency has fallen to 47 cycles (unless there is an export limit).

4. Simultaneously with 1, 2 and 3 above, endeavour to restore the frequency to 50 cycles by increasing generation. (Watch for possible transformer or circuit overloading).

5. As soon as possible report to the Grid Control Engineer.

6. Generation should not be disconnected from the Grid until all local load that can be shed has been shed and then only if there is definite evidence that a complete failure of generation would otherwise result. Generation should be disconnected without causing disruption of the main Grid transmission system, and if possible the generating plant should remain operational supplying its own auxiliaries.

Dangerous Conditions

7. The Engineer in charge at each generating station will retain the right to shut down plant if he considers that its continued running would be unsafe, or would result in breakdown of the plant.

LOAD RESTORATION/

* As revised in accordance with Chief Engineer Generation Operation's instruction for winter 1969/70.

LOAD RESTORATION

8. (a) If COMMUNICATION with the Grid Control Engineer is AVAILABLE

(i) If connected to the Grid:-

When the frequency has risen to 49.5 cycles, ask the Grid Control Engineer for permission to start restoring load.

(ii) If disconnected from the Grid:-

Advise the Grid Control Engineer as soon as generation is available for synchronising to the Grid system. The Grid Control Engineer will then decide whether the station should come in parallel with the Grid or supply local load.

(b) If COMMUNICATION with the Grid Control Engineer has FAILED

If the 'Grid Control' telephone has failed, try alternative means, e.g. Post Office telephone or V.H.F. radio (if available) to Grid Control direct or via a neighbouring generating station or Grid point.

The P.O. telephone numbers are as follows:-

..... Insert here telephone numbers of normal and emergency Grid Control Centres and neighbouring Generating Stations or Grid Points. (Directory and Ex-Directory numbers).

(c) If COMMUNICATION with the Grid Control Engineer is STILL NOT POSSIBLE

(i) If connected to the Grid:-

Restore load gradually as the frequency rises, starting when the frequency reaches 49.5 cycles.

(ii) If disconnected from the Grid:-

Resume generation as soon as possible. If possible synchronise with the Grid. Otherwise increase generation to restore local load as far as possible and synchronise with the Grid as soon as practicable. Restore remaining load (if any) with due regard to frequency and the loading of transformers and circuits.

EMERGENCY LOAD SHEDDING IRRESPECTIVE OF FREQUENCY

9. Notwithstanding the instructions above, the Grid Control Engineer (or in certain cases the Area Board Control Engineer) may instruct emergency load shedding and restoration in the pre-arranged steps of 20% IRRESPECTIVE OF SYSTEM FREQUENCY.

10./

10. Such instructions may be issued to meet emergencies not necessarily apparent to the local Operator and must be carried out IMMEDIATELY.

GENERAL

(A) Total Failure of Supply

If the busbars become dead, the station should be disconnected from the Grid by opening:-

.....

.....

.....

(B) Emergency Load Shedding Steps

The steps of approximately 20% have been pre-arranged and the Operator must act IMMEDIATELY without previous reference to Grid Control.

THERE MUST BE NO DELAY

THERE WILL BE NO TIME TO ISSUE WARNINGS

SOUTH OF SCOTLAND ELECTRICITY BOARD

ENGINEERING INSTRUCTION NO. EI/134 (2ND REVISION)

APPENDIX NO. 2

OPERATION MEMORANDUM NO. 15B

(Manned Substations)

EMERGENCY LOAD SHEDDING

in the event of

EXCEPTIONALLY SERIOUS BREAKDOWN ON THE GRID SYSTEM

The Operators at the Substation MUST act as follows:-

1.* IF THE SYSTEM FREQUENCY FALLS to 48.5 Hz low frequency relays will cause load to be shed in a pre-arranged step of 20%. Thereafter if the system frequency continues to fall the low frequency relays will shed a further 30% of load at 48.0 Hz.

2.* If the frequency continues to fall the Control Room Operator at the Substation must continue to shed load manually in pre-arranged steps in order to prevent the frequency falling below 47.0 Hz.

3. All the pre-arranged steps of load must have been shed when the frequency has fallen to 47 cycles.

4. If the Grid supply fails, open:-

.....

.....

.....

5. As soon as possible report to the Grid Control Engineer.

LOAD RESTORATION

6. (a) If COMMUNICATION with the Grid Control Engineer is AVAILABLE

(i) If the Grid switches are open, wait until the Grid becomes alive then ask the Grid Control Engineer for permission to reclose.

(ii) When the frequency has risen to 49.5 cycles ask the Grid Control Engineer for permission to start restoring load.

(b)/

* As revised in accordance with the Chief Engineer Generation Operation's instruction for winter 1969/70.

(b) If COMMUNICATION with the Grid Control Engineer has FAILED

If the 'Grid Control' telephone has failed, try alternative means, e.g. Post Office telephone or V.H.F. radio (if available) to Grid Control direct or via a neighbouring generating station or Grid point.

The P.O. telephone numbers are as follows:-

..... Insert here telephone numbers of normal and emergency Grid Control Centres and neighbouring Generating Stations or Grid Points. (Directory and Ex-Directory numbers).

(c) If COMMUNICATION with the Grid Control Engineer is STILL NOT POSSIBLE

(i) If the Grid switches are open, reclose them when the Grid becomes alive again.

(ii) Restore load gradually as the frequency rises, starting when the frequency reaches 49.5 cycles.

EMERGENCY LOAD SHEDDING IRRESPECTIVE OF FREQUENCY

7. Notwithstanding the instructions above, the Grid Control Engineer (or in certain cases the Area Board Control Engineer) may instruct emergency load shedding and restoration in the pre-arranged steps of 20% IRRESPECTIVE OF SYSTEM FREQUENCY.

8. Such instructions may be issued to meet emergencies not necessarily apparent to the Local Operator and must be carried out IMMEDIATELY.

GENERAL

Emergency Load Shedding Steps

The steps of approximately 20% have been pre-arranged and the Operator must act IMMEDIATELY without previous reference to Grid Control.

THERE MUST BE NO DELAY

THERE WILL BE NO TIME TO ISSUE WARNINGS

SOUTH OF SCOTLAND ELECTRICITY BOARD

ENGINEERING INSTRUCTION NO. E/I.134 (2ND REVISION)

APPENDIX NO. 3

OPERATION MEMORANDUM NO. 15C

(Generating Stations without Local Supplies).

PROCEDURE TO BE ADOPTED

in the event of

EXCEPTIONALLY SERIOUS BREAKDOWN ON THE GRID SYSTEM

The Control Room Operator at the Generating Station MUST act as follows:-

1. IF THE SYSTEM FREQUENCY FALLS TO 48.5 CYCLES, endeavour to restore the frequency to 50 cycles by increasing generation and maintain generation with due regard to frequency. (Watch for possible transformer or circuit overloading).

   THE LOW FREQUENCY ALARM RELAY IS FITTED SOLELY TO GIVE WARNINGS AND IS NOT TO BE REGARDED AS A STANDARD OF REFERENCE. APPROPRIATE ACTIONS ARE TO BE TAKEN ONLY ON THE EVIDENCE OF A RELIABLE FREQUENCY METER.

2. As soon as possible report to the Grid Control Engineer.

3. Generation should remain connected to the Grid for as long as possible. It should be disconnected if there is definite evidence that a complete failure of generation would otherwise result. Generation should be disconnected without causing disruption of the main Grid transmission system, and if possible the generating plant should remain operational supplying its own auxiliaries.

Dangerous Conditions

4. The Engineer in charge at each generating station will retain the right to shut down plant if he considers that its continued running would be unsafe, or would result in breakdown on the plant.

5. If disconnected from the Grid.

   (a) If COMMUNICATION with the Grid Control Engineer is AVAILABLE

   Advise the Grid Control Engineer as soon as Generation is available for synchronising to the Grid system. The Grid Control Engineer will then decide if the station should come in parallel with the Grid.

   (b) If COMMUNICATION with the Grid Control Engineer has FAILED

If/

If the 'Grid Control' telephone has failed, try alternative means, e.g. Post Office telephone or V.H.F. radio (if available) to Grid Control direct or via a neighbouring generating station or Grid point.

The P.O. telephone numbers are as follows:-

..... Insert here telephone numbers of normal and
..... emergency Grid Control Centres and neighbour-
..... ing Generating Stations or Grid Points. (Directory
..... and Ex-Directory numbers).

(c) If COMMUNICATION with the Grid Control Engineer is STILL NOT POSSIBLE

Synchronise with the Grid as soon as practicable and providing the system frequency is below 49.5 cycles increase generation with due regard to circuit loadings. For system frequencies above 49.5 cycles adjust generation to maintain a steady frequency between 49.5 cycles and 50 cycles with due regard to circuit loading.

SOUTH OF SCOTLAND ELECTRICITY BOARD

Transmission Design Memorandum SS.26 (Revision 1)

The Operational Requirements at Unattended 275 kV. Substations
(Reference should be made to TDM.SS.2 for the facilities to be provided at 132 kV. substations)

General

1. Each unattended supergrid substation will be controlled from a suitable attended point by a remote selective control and indicating scheme. Facilities required for remote selective control and standby control on site are listed below. Any additional facilities must be the subject of special consideration and be specified separately in the Transmission Construction Authorisation.

Remote Selective Control

2. The facilities which should be included where appropriate for remote control, synchronising, metering, indication, individual and grouped alarms are given in the Appendix.

Standby Control (at $1\frac{1}{2}$ breaker substations)

3. The minic diagram incorporating circuit breaker control (open/close) and indication, and indication of isolator and permanent earth switch positions should be provided at major $1\frac{1}{2}$ breaker substations and at substations which will be extended to this form.

4. Banking isolators which are controlled remotely (open only) from the attended point should also have open only control from the standby control panel.

5. Ammeters and other instruments should be located on the standby control panel.

Standby Control (at other substations)

6. At substations where synchronising is necessary and there is a choice of more than two voltage sources, facilities similar to those at $1\frac{1}{2}$ breaker substations should be provided.

7. At all other substations the standby control panel should have circuit breaker control (open/close) and indication, and indication and control (open only) of remotely controlled banking isolators. No other isolator indications should be provided on the standby control panel but, for operation purposes a small non-electrical, hand-dressed mimic diagram showing the state of the substation should be installed elsewhere in the control room.

8. Ammeters and other instruments should be located on the standby control panel.

9. At transforming stations without 275 kV. circuit breakers, the standby control panels should be combined with the 275 kV. relay panels.

Synchronising/

Synchronising

10. Substations having not more than two circuits with voltage transformers should have local synchronising facilities and a check synchronising relay only. The check synchronising relay will be so arranged that it is brought into operation when the circuit selection is made at the attended point and that it will prevent the circuit breaker being closed if the phase displacement across it exceeds a predetermined amount. Means are to be provided to over-ride the synchronising relay for energising a dead circuit.

Transformer Substation

11. Where an unattended supergrid substation is equipped with 275/132 kV. transformers, remote control of the tap changers by the operater at the attended point is required. Where 275/33 kV. transformers are installed, however, automatic voltage control should be fitted. In the latter case the remote operator should have facilities for reducing and restoring load.

12. When an unattended supergrid substation is equipped with reactors, remote control and indication of the reactor tap changers should be provided.

SOUTH OF SCOTLAND ELECTRICITY BOARD

Transmission Design Memorandum SS.26 (Revision 1)

APPENDIX

Remote Selective Control at 275 kV. Substations
(Reference should also be made to TDM.SS2 where 132 kV. is installed)

The following facilities should be included where appropriate. No other facilities shall be included unless specified in the Transmission Construction Authorisation.

Control

(1) All 275 kV. circuit breakers.
(2) 275 kV. isolators on banked circuits (open only).
(3) All supergrid transformer L.V. circuit breakers.
(4) Provision for about 12 distribution feeder circuit breakers per L.V. busbar (no control facility on cable circuits or transformer feeders).
(5) All reactor circuit breakers.
(6) Reduction and restoration of load by 5% and 10%. (275/33 kV. transformers only).
(7) Reset trip relays (one per station).
(8) Check synchronising relay in/out.
(9) Protection main/standby or in/out (one per 275 kV. circuit).
(10) Carrier test send.
(11) Tap change (275/132 kV. transformers only).
(12) Tap change (reactors).

Synchronising and Metering

(13) Full facilities for both remote and local synchronising including voltmeter readings. Substations not having more than two circuits with voltage transformers should have local synchronising facilities and a check synchronising relay only.
(14) Where full synchronising facilities are provided, single phase, ammeter readings are required, on all circuits including the L.V. side of supergrid transformers.
(15) Transformer MW. demand to be printed at controlling station (275/33 kV. transformers only). Separate pilots to be used if available.

Indication

(16) All 275 kV. circuit breakers, isolators and earth switches.
(17) All supergrid transformer L.V. circuit breakers.
(18) L.V. bus section circuit breakers or bus couplers.
(19) Provision for indication of all distribution feeder breakers.
(20) All reactor circuit breakers.
(21) Load reduced 5% and 10%.
(22) Trip relay operated (one per station).
(23) Check synchronising relay in/out.
(24) Protection on standby or out (one per 275 kV. circuit)
(25) CO_2 locked out.
(26) Carrier test receive.
(27) Tap position of 275 /132 kV. transformers
(28) Tap position of reactors.

Individual Alarms/

Individual Alarms

(29) Main protection (one per 275 kV. feeder).
(30) Back-up protection (one per 275 kV. feeder).
(31) 275 kV. transformer protection (one per transformer).
(32) Busbar protection.
(33) Intertrip channel faulty (one per equipment).
(34) Protection pilots faulty (one per equipment).
(35) Acceleration channel faulty (one per equipment).
(36) Carrier fail (one per equipment).
(37) V.T. supply fail (one per feeder but only if V.T.'s used for protective gear).
(38) Low air-pressure lockout (one per circuit).
(39) Standby earth fault (1st stage of two stages only). (One per transformer).
(40) CO_2 operated.
(41) 110 V. battery earth fault.
(42) Provision for alarms direct to C.I.S. which are not displayed at the controlling point, e.g. feeder overload, watts direction, vars direction etc.
(43) High speed ammeter operated (one per substation).

Grouped Alarms

(44) Transformer Alarm:- One per main transformer, initiated by any following:-

(a) Main transformer Buchholz gas.
(b) Auxiliary transformer Buchholz gas.
(c) Main transformer, winding temperature.

(45) Reactor Alarm:- One per reactor initiated by any of the following:-

(a) Reactor, Buchholz gas.
(b) Reactor, winding temperature.

The undermentioned alarms are grouped by operational responsibilities so that the appropriate engineer may be notified.

(46) Transmission General Alarm - One common alarm initiated by any of the following devices:-

(a) Low air pressure (air blast of pneumatically operated switchgear).
(b) 110 V. battery charger fail.
(c) 50 V. battery charger fail.
(d) Voltage control faulty.
(e) 24 V. battery charger fail (if required).

(47) Protection General Alarm - One common alarm initiated by any of the following devices:-

(a) Trip circuit faulty.
(b) Busbar protection defective.
(c) Supervision supply faulty.

(48)/

(48) Telecommunications General Alarm - One common alarm initiated by any of the following devices:-

(a) Fuse alarms.
(b) Substation 50 V. battery low.

(49) Distribution General Alarm - One common alarm initiated by any of the following devices:-

(a) Local distribution transformer Buchholz gas.
(b) Local distribution transformer winding temperature.
(c) Tripping of any circuit breakers not indicated directly.
(d) Any additional devices considered necessary.

APPENDIX X

D.I. 9/1

SOUTH OF SCOTLAND ELECTRICITY BOARD

ENGINEERING INSTRUCTION NO. EI/134 (2ND REVISION)
(Limited Circulation)

System Operation Memoranda Nos. 15A, 15B and 15C
Load Shedding in the event of exceptionally
Serious Breakdown on the Grid System

Purpose:

(1) This Instruction deals with emergency load shedding arrangements in the event of exceptionally serious breakdown on the grid system and is a revision of EI/134 (revised) dated 10th July, 1962.

(2) C.E.G.B. Revision of Emergency Load Shedding

Procedure

The Station Superintendents' Meeting of 14th December, 1965, approved a C.E.G.B. paper on the revision of Emergency Load Shedding Procedure. At the Area Engineers' Meeting held on 6th January, 1966, the Chief Transmission/Distribution Engineer recommended that the relevant EI/134 be amended in line with this revision and issued without delay.

(3) The instructions which deal separately with generating stations, substations and generating stations without local supplies are attached as Appendix No. 1, Appendix No. 2 and Appendix No. 3 respectively to this Instruction.. Copies mounted on cards are suitable for placing in a prominent position in Control Rooms.

Scope of Appendix No. 1 (Generating Stations with local supplies)

(4) The Control Room staff at generating stations will be required to follow the instructions laid down in this Appendix in the event of a serious drop of frequency on the system, without prior warning to the Grid Control Engineer or to the Areas. The Grid Control Engineer should however be informed of any action taken as soon as possible thereafter. The procedure for dealing with such an emergency has already been agreed and it is only necessary for Area Engineers to review the instructions already given to Generation Stations' staffs for emergency switching in steps of 20%. The instructions should be sent in triplicate to the Chief Engineer's Department. One of the copies will then be sent to the Generating Engineer (Operation) with a further copy for the System Operation Engineer. So far as possible feeders have been, or will be, arranged so that domestic and other less essential loads are disconnected first. Feeders supplying collieries and other essential loads should be the last to be disconnected.

Scope of Appendix No. 2 (Substations)

(5) Instructions as to the order in which the load shedding referred to in this Appendix shall be carried out, will come from the appropriate Area Engineer. It is important that Area Engineers who have continuously staffed substations under their control should ensure that the operating staffs have copies of this document available to them and are fully conversant with the procedure to be adopted in the event of a sudden drop in frequency to 48.5 cycles per second or lower. As in the case of Generating Stations, the sequence with which feeders would be switched out in approximately 20% steps must be given to the operating staff by the Area Engineer, the less essential feeders being/

being the first to be switched out. Copies of the Area Engineers' instructions to the operating staff of the continuously manned sub-stations where emergency load shedding is to be carried out, should be sent in triplicate to the Chief Engineer's Department. One of the copies will then be sent to the Generation Engineer (Operation) with a further copy for the System Operation Engineer.

Scope of Appendix No. 3 (Generating Stations without Local Supplies)

(6) The Control Room staff at generating stations will be required to follow the instructions laid down in this Appendix in the event of a serious drop of frequency on the system, without prior warning to the Grid Control Engineer of to the Areas. The Grid Control Engineer should however be informed of any action taken as soon as possible thereafter.

H. MORRIS
Chief Engineer.

SOUTH OF SCOTLAND ELECTRICITY BOARD

ENGINEERING INSTRUCTION NO. EI/134 (2ND REVISION)

APPENDIX NO. 1

OPERATION MEMORANDUM NO. 15A

(Generating Stations with Local Supplies)

EMERGENCY LOAD SHEDDING

in the event of

EXCEPTIONALLY SERIOUS BREAKDOWN ON THE GRID SYSTEM

The Control Room Operator at the Generating Station MUST act as follows:-

LOAD SHEDDING

1.* IF THE SYSTEM FREQUENCY FALLS to 48.5 Hz low frequency relays will cause load to be shed in a pre-arranged step of 20%. Thereafter if the system frequency continues to fall the low frequency relays will shed a further 30% of load at 48.0 Hz.

2.* If the frequency continues to fall the Control Room Operator at the Generating Station must continue to shed load manually in pre-arranged steps in order to prevent the frequency falling below 47.0 Hz.

3. All the pre-arranged steps of load must have been shed when the frequency has fallen to 47 cycles (unless there is an export limit).

4. Simultaneously with 1, 2 and 3 above, endeavour to restore the frequency to 50 cycles by increasing generation. (Watch for possible transformer or circuit overloading).

5. As soon as possible report to the Grid Control Engineer.

6. Generation should not be disconnected from the Grid until all local load that can be shed has been shed and then only if there is definite evidence that a complete failure of generation would otherwise result. Generation should be disconnected without causing disruption of the main Grid transmission system, and if possible the generating plant should remain operational supplying its own auxiliaries.

Dangerous Conditions

7. The Engineer in charge at each generating station will retain the right to shut down plant if he considers that its continued running would be unsafe, or would result in breakdown of the plant.

LOAD RESTORATION/

* As revised in accordance with Chief Engineer Generation Operation's instruction for winter 1969/70.

LOAD RESTORATION

8. (a) If COMMUNICATION with the Grid Control Engineer is AVAILABLE

(i) If connected to the Grid:-

When the frequency has risen to 49.5 cycles, ask the Grid Control Engineer for permission to start restoring load.

(ii) If disconnected from the Grid:-

Advise the Grid Control Engineer as soon as generation is available for synchronising to the Grid system. The Grid Control Engineer will then decide whether the station should come in parallel with the Grid or supply local load.

(b) If COMMUNICATION with the Grid Control Engineer has FAILED

If the 'Grid Control' telephone has failed, try alternative means, e.g. Post Office telephone or V.H.F. radio (if available) to Grid Control direct or via a neighbouring generating station or Grid point.

The P.O. telephone numbers are as follows:-

..... Insert here telephone numbers of normal and emergency Grid Control Centres and neighbouring Generating Stations or Grid Points. (Directory and Ex-Directory numbers).

(c) If COMMUNICATION with the Grid Control Engineer is STILL NOT POSSIBLE

(i) If connected to the Grid:-

Restore load gradually as the frequency rises, starting when the frequency reaches 49.5 cycles.

(ii) If disconnected from the Grid:-

Resume generation as soon as possible. If possible synchronise with the Grid. Otherwise increase generation to restore local load as far as possible and synchronise with the Grid as soon as practicable. Restore remaining load (if any) with due regard to frequency and the loading of transformers and circuits.

EMERGENCY LOAD SHEDDING IRRESPECTIVE OF FREQUENCY

9. Notwithstanding the instructions above, the Grid Control Engineer (or in certain cases the Area Board Control Engineer) may instruct emergency load shedding and restoration in the pre-arranged steps of 20% IRRESPECTIVE OF SYSTEM FREQUENCY.

10./

10. Such instructions may be issued to meet emergencies not necessarily apparent to the local Operator and must be carried out IMMEDIATELY.

GENERAL

(A) Total Failure of Supply

If the busbars become dead, the station should be disconnected from the Grid by opening:-

.....

.....

.....

(B) Emergency Load Shedding Steps

The steps of approximately 20% have been pre-arranged and the Operator must act IMMEDIATELY without previous reference to Grid Control.

THERE MUST BE NO DELAY

THERE WILL BE NO TIME TO ISSUE WARNINGS

SOUTH OF SCOTLAND ELECTRICITY BOARD

ENGINEERING INSTRUCTION NO. EI/134 (2ND REVISION)

APPENDIX NO. 2

OPERATION MEMORANDUM NO. 15B

(Manned Substations)

EMERGENCY LOAD SHEDDING

in the event of

EXCEPTIONALLY SERIOUS BREAKDOWN ON THE GRID SYSTEM

The Operators at the Substation MUST act as follows:-

1.* IF THE SYSTEM FREQUENCY FALLS to 48.5 Hz low frequency relays will cause load to be shed in a pre-arranged step of 20%. Thereafter if the system frequency continues to fall the low frequency relays will shed a further 30% of load at 48.0 Hz.

2.* If the frequency continues to fall the Control Room Operator at the Substation must continue to shed load manually in pre-arranged steps in order to prevent the frequency falling below 47.0 Hz.

3. All the pre-arranged steps of load must have been shed when the frequency has fallen to 47 cycles.

4. If the Grid supply fails, open:-

.....

.....

.....

5. As soon as possible report to the Grid Control Engineer.

LOAD RESTORATION

6. (a) If COMMUNICATION with the Grid Control Engineer is AVAILABLE

(i) If the Grid switches are open, wait until the Grid becomes alive then ask the Grid Control Engineer for permission to reclose.

(ii) When the frequency has risen to 49.5 cycles ask the Grid Control Engineer for permission to start restoring load.

(b)/

* As revised in accordance with the Chief Engineer Generation Operation's instruction for winter 1969/70.

(b) If COMMUNICATION with the Grid Control Engineer has FAILED

If the 'Grid Control' telephone has failed, try alternative means, e.g. Post Office telephone or V.H.F. radio (if available) to Grid Control direct or via a neighbouring generating station or Grid point.

The P.O. telephone numbers are as follows:-

..... Insert here telephone numbers of normal and emergency Grid Control Centres and neighbouring Generating Stations or Grid Points. (Directory and Ex-Directory numbers).

(c) If COMMUNICATION with the Grid Control Engineer is STILL NOT POSSIBLE

(i) If the Grid switches are open, reclose them when the Grid becomes alive again.

(ii) Restore load gradually as the frequency rises, starting when the frequency reaches 49.5 cycles.

EMERGENCY LOAD SHEDDING IRRESPECTIVE OF FREQUENCY

7. Notwithstanding the instructions above, the Grid Control Engineer (or in certain cases the Area Board Control Engineer) may instruct emergency load shedding and restoration in the pre-arranged steps of 20% IRRESPECTIVE OF SYSTEM FREQUENCY.

8. Such instructions may be issued to meet emergencies not necessarily apparent to the Local Operator and must be carried out IMMEDIATELY.

GENERAL

Emergency Load Shedding Steps

The steps of approximately 20% have been pre-arranged and the Operator must act IMMEDIATELY without previous reference to Grid Control.

THERE MUST BE NO DELAY

THERE WILL BE NO TIME TO ISSUE WARNINGS

SOUTH OF SCOTLAND ELECTRICITY BOARD

ENGINEERING INSTRUCTION NO. E/I.134 (2ND REVISION)

APPENDIX NO. 3

OPERATION MEMORANDUM NO. 15C

(Generating Stations without Local Supplies).

PROCEDURE TO BE ADOPTED

in the event of

EXCEPTIONALLY SERIOUS BREAKDOWN ON THE GRID SYSTEM

The Control Room Operator at the Generating Station MUST act as follows:-

1. IF THE SYSTEM FREQUENCY FALLS TO 48.5 CYCLES, endeavour to restore the frequency to 50 cycles by increasing generation and maintain generation with due regard to frequency. (Watch for possible transformer or circuit overloading).

   THE LOW FREQUENCY ALARM RELAY IS FITTED SOLELY TO GIVE WARNINGS AND IS NOT TO BE REGARDED AS A STANDARD OF REFERENCE. APPROPRIATE ACTIONS ARE TO BE TAKEN ONLY ON THE EVIDENCE OF A RELIABLE FREQUENCY METER.

2. As soon as possible report to the Grid Control Engineer.

3. Generation should remain connected to the Grid for as long as possible. It should be disconnected if there is definite evidence that a complete failure of generation would otherwise result. Generation should be disconnected without causing disruption of the main Grid transmission system, and if possible the generating plant should remain operational supplying its own auxiliaries.

Dangerous Conditions

4. The Engineer in charge at each generating station will retain the right to shut down plant if he considers that its continued running would be unsafe, or would result in breakdown on the plant.

5. If disconnected from the Grid.

   (a) If COMMUNICATION with the Grid Control Engineer is AVAILABLE

   Advise the Grid Control Engineer as soon as Generation is available for synchronising to the Grid system. The Grid Control Engineer will then decide if the station should come in parallel with the Grid.

   (b) If COMMUNICATION with the Grid Control Engineer has FAILED

If/

If the 'Grid Control' telephone has failed, try alternative means, e.g. Post Office telephone or V.H.F. radio (if available) to Grid Control direct or via a neighbouring generating station or Grid point.

The P.O. telephone numbers are as follows:-

..... Insert here telephone numbers of normal and
..... emergency Grid Control Centres and neighbour-
..... ing Generating Stations or Grid Points. (Directory
..... and Ex-Directory numbers).

(c) If COMMUNICATION with the Grid Control Engineer is STILL NOT POSSIBLE

Synchronise with the Grid as soon as practicable and providing the system frequency is below 49.5 cycles increase generation with due regard to circuit loadings. For system frequencies above 49.5 cycles adjust generation to maintain a steady frequency between 49.5 cycles and 50 cycles with due regard to circuit loading.

APPENDIX XI

SOUTH OF SCOTLAND ELECTRICITY BOARD

Transmission Design Memorandum SS.26 (Revision 1)

The Operational Requirements at Unattended 275 kV. Substations
(Reference should be made to TDM.SS.2 for the facilities to be provided at 132 kV. substations)

General

1. Each unattended supergrid substation will be controlled from a suitable attended point by a remote selective control and indicating scheme. Facilities required for remote selective control and standby control on site are listed below. Any additional facilities must be the subject of special consideration and be specified separately in the Transmission Construction Authorisation.

Remote Selective Control

2. The facilities which should be included where appropriate for remote control, synchronising, metering, indication, individual and grouped alarms are given in the Appendix.

Standby Control (at 1½ breaker substations)

3. The minic diagram incorporating circuit breaker control (open/close) and indication, and indication of isolator and permanent earth switch positions should be provided at major 1½ breaker substations and at substations which will be extended to this form.

4. Banking isolators which are controlled remotely (open only) from the attended point should also have open only control from the standby control panel.

5. Ammeters and other instruments should be located on the standby control panel.

Standby Control (at other substations)

6. At substations where synchronising is necessary and there is a choice of more than two voltage sources, facilities similar to those at 1½ breaker substations should be provided.

7. At all other substations the standby control panel should have circuit breaker control (open/close) and indication, and indication and control (open only) of remotely controlled banking isolators. No other isolator indications should be provided on the standby control panel but, for operation purposes a small non-electrical, hand-dressed mimic diagram showing the state of the substation should be installed elsewhere in the control room.

8. Ammeters and other instruments should be located on the standby control panel.

9. At transforming stations without 275 kV. circuit breakers, the standby control panels should be combined with the 275 kV. relay panels.

Synchronising/

Synchronising

10. Substations having not more than two circuits with voltage transformers should have local synchronising facilities and a check synchronising relay only. The check synchronising relay will be so arranged that it is brought into operation when the circuit selection is made at the attended point and that it will prevent the circuit breaker being closed if the phase displacement across it exceeds a predetermined amount. Means are to be provided to over-ride the synchronising relay for energising a dead circuit.

Transformer Substation

11. Where an unattended supergrid substation is equipped with 275/132 kV. transformers, remote control of the tap changers by the operater at the attended point is required. Where 275/33 kV. transformers are installed, however, automatic voltage control should be fitted. In the latter case the remote operator should have facilities for reducing and restoring load.

12. When an unattended supergrid substation is equipped with reactors, remote control and indication of the reactor tap changers should be provided.

SOUTH OF SCOTLAND ELECTRICITY BOARD

Transmission Design Memorandum SS.26 (Revision 1)

APPENDIX

Remote Selective Control at 275 kV. Substations
(Reference should also be made to TDM.SS2 where 132 kV. is installed)

The following facilities should be included where appropriate. No other facilities shall be included unless specified in the Transmission Construction Authorisation.

Control

(1) All 275 kV. circuit breakers.
(2) 275 kV. isolators on banked circuits (open only).
(3) All supergrid transformer L.V. circuit breakers.
(4) Provision for about 12 distribution feeder circuit breakers per L.V. busbar (no control facility on cable circuits or transformer feeders).
(5) All reactor circuit breakers.
(6) Reduction and restoration of load by 5% and 10%. (275/33 kV. transformers only).
(7) Reset trip relays (one per station).
(8) Check synchronising relay in/out.
(9) Protection main/standby or in/out (one per 275 kV. circuit).
(10) Carrier test send.
(11) Tap change (275/132 kV. transformers only).
(12) Tap change (reactors).

Synchronising and Metering

(13) Full facilities for both remote and local synchronising including voltmeter readings. Substations not having more than two circuits with voltage transformers should have local synchronising facilities and a check synchronising relay only.
(14) Where full synchronising facilities are provided, single phase, ammeter readings are required, on all circuits including the L.V. side of supergrid transformers.
(15) Transformer MW. demand to be printed at controlling station (275/33 kV. transformers only). Separate pilots to be used if available.

Indication

(16) All 275 kV. circuit breakers, isolators and earth switches.
(17) All supergrid transformer L.V. circuit breakers.
(18) L.V. bus section circuit breakers or bus couplers.
(19) Provision for indication of all distribution feeder breakers.
(20) All reactor circuit breakers.
(21) Load reduced 5% and 10%.
(22) Trip relay operated (one per station).
(23) Check synchronising relay in/out.
(24) Protection on standby or out (one per 275 kV. circuit)
(25) CO_2 locked out.
(26) Carrier test receive.
(27) Tap position of 275 /132 kV. transformers
(28) Tap position of reactors.

Individual Alarms/

Individual Alarms

(29) Main protection (one per 275 kV. feeder).
(30) Back-up protection (one per 275 kV. feeder).
(31) 275 kV. transformer protection (one per transformer).
(32) Busbar protection.
(33) Intertrip channel faulty (one per equipment).
(34) Protection pilots faulty (one per equipment).
(35) Acceleration channel faulty (one per equipment).
(36) Carrier fail (one per equipment).
(37) V.T. supply fail (one per feeder but only if V.T.'s used for protective gear).
(38) Low air-pressure lockout (one per circuit).
(39) Standby earth fault (1st stage of two stages only). (One per transformer).
(40) CO_2 operated.
(41) 110 V. battery earth fault.
(42) Provision for alarms direct to C.I.S. which are not displayed at the controlling point, e.g. feeder overload, watts direction, vars direction etc.
(43) High speed ammeter operated (one per substation).

Grouped Alarms

(44) Transformer Alarm:- One per main transformer, initiated by any following:-

(a) Main transformer Buchholz gas.
(b) Auxiliary transformer Buchholz gas.
(c) Main transformer, winding temperature.

(45) Reactor Alarm:- One per reactor initiated by any of the following:-

(a) Reactor, Buchholz gas.
(b) Reactor, winding temperature.

The undermentioned alarms are grouped by operational responsibilities so that the appropriate engineer may be notified.

(46) Transmission General Alarm - One common alarm initiated by any of the following devices:-

(a) Low air pressure (air blast of pneumatically operated switchgear).
(b) 110 V. battery charger fail.
(c) 50 V. battery charger fail.
(d) Voltage control faulty.
(e) 24 V. battery charger fail (if required).

(47) Protection General Alarm - One common alarm initiated by any of the following devices:-

(a) Trip circuit faulty.
(b) Busbar protection defective.
(c) Supervision supply faulty.

(48)/

(48) Telecommunications General Alarm - One common alarm initiated by any of the following devices:-

(a) Fuse alarms.
(b) Substation 50 V. battery low.

(49) Distribution General Alarm - One common alarm initiated by any of the following devices:-

(a) Local distribution transformer Buchholz gas.
(b) Local distribution transformer winding temperature.
(c) Tripping of any circuit breakers not indicated directly.
(d) Any additional devices considered necessary.